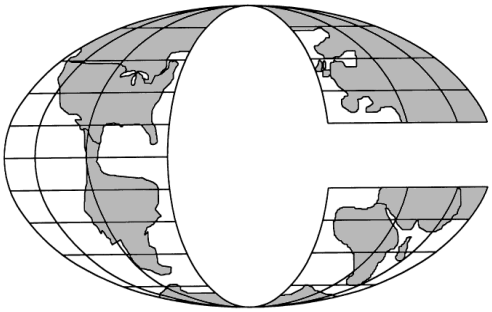
Prepared for

Pedricktown Site Group

FOCUSED FEASIBILITY STUDY

FOR
GROUNDWATER REMEDIATION
NL Industries Superfund Site
Pedricktown, New Jersey

November 2007
Revised August 2008



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TABLES

Table 1
Data Summary for the April 2007 Groundwater Sampling
NL Industries Superfund Site
Pedricktown, New Jersey

	Well Number												
Parameter (ug/L)	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**22**	**23**	**24**	**26**	**27**	**RAO**
Inorganics													
Total Cadmium	**110 J**	ND	ND	ND	ND	ND	ND	**7.3 J**	**25.8 J**	ND	**12.6 J**	**8.5**	4
Dissolved Cadmium	**113 J**	ND	ND	ND	ND	ND	ND	**7.2 J**	**26.7 J**	ND	**13 J**	**7.1**	4
Total Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.4 J	**6.2**	5
Dissolved Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.6	5
Organics													
Acetone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	700
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.66 J	ND	ND	--
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6
Isobutane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
1,1-Dichloroethane	0.99	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	70
cis-1,2-Dichloroethene	0.68	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
Methylene Chloride	0.39 U	ND	0.64 U	0.42 U	0.36 U	0.26 U	0.31 U	ND	ND	ND	ND	0.4 U	--
Methyl tert-butyl Ether	ND	ND	ND	ND	ND	0.69	ND	ND	ND	ND	ND	ND	--
Tetrachloroethene	**1.1**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1,000
1,1,1-Trichloroethane	2.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	26
Trichloroethene	0.29 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
Vinyl Chloride	ND	**9.3**	ND	ND	ND	ND	ND	ND	ND	**4.9**	ND	ND	0.08

U = Parameter was flagged in data validation and are considered non-detects.
(1) 100 is a duplicate sample obtained from monitoring well 28.
(2) 101 is a duplicate sample obtained from monitoring well KDR.
(3) 102 is a duplicate sample obtained from monitoring well 31.
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(5) FB-1 is a field blank collected with water supplied by Chemtech, water used for final rinse during decontamination events.
(6) Four trip blanks were included with the samples. TB-1, TB-2, TB-3, and TB-4.
N/A = Not Applicable
ND = Non Detect
RDL = Required Detection Limit (Contract)
MDL = Method Detection Limit (Instrument)
RAO = Remedial Action Objective. RAO is the lowest value out of NJGWQS, NJMCL, or MCL as defined in the ROD. If not specified in ROD, RAO left blank.
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NL Industries Superfund Site
Pedricktown, New Jersey

	Well Number													
Parameter (ug/L)	**28**	**MW-100***	**30R**	**31**	**102[3]**	**32**	**33**	**34**	**JS**	**JDR**	**KSR**	**KDR**	**101[2]**	**RAO**
Inorganics														
Total Cadmium	**151**	**149**	**163 J**	1.5 J	1.2 J	ND	3.0 J	ND	3.9 J	**54.5 J**	**7.8 J**	**141 J**	**139 J**	4
Dissolved Cadmium	**163**	**154**	**169 J**	1 J	ND	ND	ND	ND	3 J	**60.8 J**	3.8 U	**166 J**	**144 J**	4
Total Lead	ND	ND	ND	**20.6 J**	**17 J**	ND	ND	**16.3**	1.0 J	ND	ND	ND	ND	5
Dissolved Lead	ND	ND	1.6 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5
Organics														
Acetone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	700
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.98	6
Isobutane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	70
cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
Methylene Chloride	0.35 U	0.29 U	ND	3.0 U	ND	ND	0.45 U	0.36 U	ND	0.5 U	0.33 U	0.28 U	ND	--
Methyl tert-butyl Ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1,000
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	26
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
Vinyl Chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.08

J = Data indicates the presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.
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	Well Number						QA/QC Samples							
Parameter (ug/L)	**SS**	**SD**	**NS**	**ND**	**OS**	**BR**	**RB-1[4]**	**RB-2[4]**	**FB-1[5]**	**TB-1[6]**	**TB-2[6]**	**TB-3[6]**	**TB-4[6]**	**RAO**
Inorganics														
Total Cadmium	**10.6 J**	**149 J**	1.5 U	ND	3.9 J	ND	ND	ND	ND	NA	NA	NA	NA	4
Dissolved Cadmium	**11.8 J**	**156 J**	1.4 U	ND	**4.2 J**	1.1 U	ND	1.1 U	ND	NA	NA	NA	NA	4
Total Lead	**82.9**	**31**	**41.6 J**	**22.2 J**	**388**	ND	ND	ND	ND	NA	NA	NA	NA	5
Dissolved Lead	**13**	**90.4**	ND	ND	**320**	ND	ND	ND	ND	NA	NA	NA	NA	5
Organics														
Acetone	ND	ND	ND	ND	ND	ND	ND	ND	9.4	ND	ND	ND	ND	700
Benzene	ND	0.68	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
Chloroform	ND	2.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6
Isobutane	ND	ND	ND	ND	ND	ND	ND	ND	2.7 J	ND	ND	ND	ND	--
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	70
cis-1,2-Dichloroethene	ND	0.35 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
Methylene Chloride	ND	0.5 U	ND	ND	ND	ND	2.2 U	2 U	3 U	0.55 U	0.84 U	0.45 U	2.5 U	--
Methyl tert-butyl Ether	ND	ND	ND	0.41 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4
Toluene	ND	0.5 J	ND	ND	ND	ND	0.25 J	0.33 J	0.37 J	ND	ND	ND	ND	1,000
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	26
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
Vinyl Chloride	ND	**1.3**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.08

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Well ID	**11**								**12**						
Year	1983	1988	1989	1990	1997	1998	2004	2007	1989	1990	1997	1998	2004	2007	**RAO**
Inorganic Compounds (ug/L)															
Total Cadmium	NM	NM	NM	NM	**47 JE**	**240**	**416**	**110 J**	NM	NM	ND	ND	ND	ND	4
Dissolved Cadmium	NM	**134**	**210**	NM	**8 J**	**253**	**415**	**113 J**	ND	NM	NM	0.9 B	ND	ND	4
Total Lead	**460**	NM	NM	NM	**25.2 J**	1.4 JB	4	ND	NM	NM	ND	ND	4.9	ND	5
Dissolved Lead	NM	**6 J**	NM	NM	ND	ND	**5.1**	ND	NM	2.3	NM	ND	ND	ND	5
Volatile Organic Compounds (ug/L)															
Total Organics	NM	NM	5124	2974	1.52	NM	15	5.86	NM	NM	11.3	NM	3.7	9.3	NA

Notes:
NJGWQS = New Jersey Groundwater Quality Standards
NJMCL = New Jersey Maximum Contaminant Level
PQL = Practical Quantitation Limit
* = Original well damaged during the remedial action, replaced in 2004
RAO = Remedial Action Objective. RAO is the lowest value out of NJGWQS, NJMCL, or MCL as defined in the ROD.
ND = Not detected above the laboratories limit of detection (LOD)
NM = Not Measured
NA = Not Applicable
J = Value is approximate
B = Value was lesser than the Contract-required LOD, but greater than the instrument LOD
E = Estimated value based on the presence of an interference
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The 2004 data quality is suspected to have been affected by freezing temperatures during sample collection.

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Pedricktown, New Jersey

Well ID	**13**	**14**	**15**					**16**	**17**				**22**			
Year	2007	2007	1989	1990	1997	2004	2007	2007	1989	1990	1997	2007	1998	2004	2007	**RAO**
Inorganic Compounds (ug/L)																
Total Cadmium	ND	ND	NM	NM	ND	NM	ND	ND	NM	NM	2.3 JE	ND	**92**	**15.6**	**7.3 J**	4
Dissolved Cadmium	ND	ND	ND	ND	**20 JE**	NM	ND	ND	ND	ND	NM	ND	**86.2**	ND	**7.2 J**	4
Total Lead	ND	ND	NM	NM	4.5	NM	ND	ND	NM	NM	**5.5 J**	ND	1.9 B	**5.7**	ND	5
Dissolved Lead	ND	ND	NM	2.1	ND	NM	ND	ND	NM	1.6	NM	ND	4.9	ND	ND	5
Volatile Organic Compounds (ug/L)																
Total Organics	ND	ND	NM	NM	ND	NM	ND	0.69	NM	NM	1.9	ND	NM	ND	ND	NA

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Well ID	**23**			**24**		**26**			**27**			**28**			
Year	1998	2004	2007	2004	2007	1998	2004	2007	1998	2004	2007	1998	2004	2007	**RAO**
Inorganic Compunds (ug/L)															
Total Cadmium	**12.9**	**74.8**	**25.8 J**	ND	ND	ND	**31**	**13 J**	**14.8**	2.2 J	**8.5**	**383**	**250**	**151**	4
Dissolved Cadmium	**12.1**	ND	**26.7 J**	ND	ND	**42 JB**	ND	**13 J**	**14.5**	ND	**7.1**	**360**	ND	**163**	4
Total Lead	1.6 B	3.6	ND	4.9	ND	ND	**5.6**	1.4 J	**19.9**	4.2	**6.2**	**15.4**	4.2	ND	5
Dissolved Lead	1.5 B	ND	ND	4.3	ND	**49 JB**	ND	ND	**21**	ND	3.3	**13**	ND	ND	5
Volatile Organic Compounds (ug/L)															
Total Organics	NM	ND	ND	5.26	5.56	NM	ND	ND	NM	ND	ND	NM	ND	ND	NA

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Well ID	30R*			31			32			33			34			
Year	1998	2004	2007	1998	2004	2007	1998	2004	2007	1998	2004	2007	1998	2004	2007	RAO
Inorganic Compounds (ug/L)																
Total Cadmium	**327**	**136**	**163 J**	ND	ND	1.5 J	ND	ND	ND	ND	0.5 J	3.0 J	ND	ND	ND	4
Dissolved Cadmium	**341**	ND	**169 J**	ND	ND	1.0 J	ND	ND	ND	ND	0.4 J	ND	ND	ND	ND	4
Total Lead	**37.4**	3.2	ND	ND	**34.3**	**20.6 J**	ND	2.3 J	ND	1.6 B	ND	ND	**8.6**	ND	**16.3**	5
Dissolved Lead	**36.8**	ND	1.6 J	ND	2.8 J	ND	ND	ND	ND	ND	ND	ND	ND	2.4 J	ND	5
Volatile Organic Compounds (ug/L)																
Total Organics	NM	ND	ND	NM	ND	ND	NM	ND	ND	NM	ND	ND	NM	ND	ND	NA

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NL Industries Superfund Site
Pedricktown, New Jersey

Well ID	**JS**			**JDR***						**KSR***					
Year	1998	2004	2007	1983	1988	1997	1998	2004	2007	1983	1988	1997	2004	2007	**RAO**
Inorganic Compounds (ug/L)															
Total Cadmium	1.4 B	3.9 J	3.9 J	NM	NM	**193 J**	**200**	**14.8**	**54.5 J**	NM	NM	**63 J**	**15.1**	**7.8 J**	4
Dissolved Cadmium	1.5 B	1.5 J	3.0 J	NM	**103**	**7.1**	**207**	**12.6**	**60.8 J**	NM	**173**	**172**	**15.8**	ND	4
Total Lead	ND	4	1.0 J	**390**	NM	4.1 B	ND	**12.6**	ND	**2560**	NM	**328**	**5**	ND	5
Dissolved Lead	ND	3	ND	NM	**14**	ND	ND	**6.8**	ND	NM	**3130**	ND	4.1	ND	5
Volatile Organic Compounds (ug/L)															
Total Organics	NM	ND	ND	NM	NM	0.27	NM	ND	ND	NM	NM	ND	ND	ND	NA

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Pedricktown, New Jersey

Well ID	KDR*							SS			
Year	1983	1988	1989	1990	1997	2004	2007	1998	2004	2007	RAO
Inorganic Compounds (ug/L)											
Total Cadmium	NM	NM	NM	**103**	**16.5 J**	**97.1**	**141 J**	**22.7**	**105**	**10.6 J**	4
Dissolved Cadmium	NM	**291**	**113**	NM	**19.0 J**	**92.8**	**166 J**	**18.2**	ND	**11.8 J**	4
Total Lead	**270**	NM	NM	**14**	**328**	**11.9**	ND	ND	**321**	**82.9**	5
Dissolved Lead	NM	**61 J**	**19 J**	NM	ND	**11.2**	ND	ND	ND	**13**	5
Volatile Organic Compounds (ug/L)											
Total Organics	NM	NM	NM	NM	ND	0.96	ND	NM	1.9	ND	NA

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Well ID	SD								NS							
Year	1983	1988	1989	1990	1997	1998	2004	2007	1983	1988	1989	1997	1998	2004	2007	RAO
Inorganic Compounds (ug/L)																
Total Cadmium	NM	NM	NM	NM	**237 JE**	**185**	**134**	**149 J**	NM	NM	NM	ND	0.8 B	0.6 J	ND	4
Dissolved Cadmium	NM	**1010**	**963**	**997**	NM	**169**	ND	**156 J**	NM	**9**	**4**	NM	ND	ND	ND	4
Total Lead	**2960**	NM	NM	NM	**51.1 J**	**25.6 J**	**36.8**	**31**	**1180**	NM	NM	**8.2**	**5.1 J**	**7.4**	**41.6 J**	5
Dissolved Lead	NM	**294**	**84.0 J**	**56**	NM	**24.0 J**	ND	**90.4**	NM	**45 J**	**10 J**	NM	ND	2.3 J	ND	5
Volatile Organic Compounds (ug/L)																
Total Organics	NM	NM	6	13	20	NM	17.93	5.23	NM	NM	NM	ND	NM	ND	ND	NA

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Well ID	ND			OS			BR							
Year	1998	2004	2007	1998	2004	2007	1983	1988	1990	1997	1998	2004	2007	RAO
Inorganic Compounds (ug/L)														
Total Cadmium	0.4 B	ND	ND	**4.7 B**	1.4 J	3.9 J	NM	**15**	NM	**13.5 E**	**16**	1.3 J	ND	4
Dissolved Cadmium	1.5 B	ND	ND	2.9 B	1.4 J	4.2 J	NM	ND	NM	NM	15	1.4 J	ND	4
Total Lead	ND	**18.8**	**22.2 J**	**476 J**	**456**	**388**	**250**	**18**	NM	1.9 B	ND	**5.6**	ND	5
Dissolved Lead	ND	10.6	ND	6.8 J	94.9	320	NM	5.0 J	NM	NM	1.4 JB	3.9	ND	5
Volatile Organic Compounds (ug/L)														
Total Organics	NM	0.34	0.41	NM	ND	ND	NM	NM	89.3	79	NM	ND	ND	NA

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PQL = Practical Quantitation Limit
* = Original well damaged during the remedial action, replaced in 2004
RAO = Remedial Action Objective. RAO is the lowest value out of NJGWQS, NJMCL, or MCL as defined in the ROD.
ND = Not detected above the laboratories limit of detection (LOD)
NM = Not Measured
NA = Not Applicable
J = Value is approximate
B = Value was lesser than the Contract-required LOD, but greater than the instrument LOD
E = Estimated value based on the presence of an interference
Shaded and bold values indicate an exceedence of the NJGWQS
The 2004 data quality is suspected to have been affected by freezing temperatures during sample collection.

Table 3
Recommended Groundwater Monitoring Locations for MNA Remedy
NL Industries Superfund Site
Pedricktown, New Jersey

Monitoring Well	Well Depth [1]	Screened Interval [2]	Aquifer Zone [3]	Rationale
BR	39	33-39	UA	western limits
JS	15.37	5-15	UA	eastern limits
JDR	27.26	17-27	UA	eastern limits
KSR	15	5-15	UA	central area
KDR	24	14-24	UA	central area
NS	16.5	6.5-16.5	UA	western limits
ND	24	14-24	UA	western limits
OS	21.3	6.3-21.3	UA	western limits
SS	16.4	6.4-16.4	UA	central area
SD	29.4	17.4-29.4	UA	central area
11	54.1	34.1-54.1	UA	western limits
14	46.6	26.6-46.6	UA	northern limits
15	25	10-25	UA	northern limits
22	16	11-16	UA	eastern limits
23	24	24-34	UA	eastern limits
26	22	12-22	UA	northern limits
27	15	5-15	UA	central area
28	30	20-30	UA	central area
30R	28.71	17-27	UA	central area
31	15	5-15	UA	southern limits
33	10	5-10	UA	northern limts
MW-1[4]	TBD	TBD	UA	western limits
MW-2[4]	TBD	TBD	UA	western limits

[1] Depth to bottom of well in feet below top of casing (TOC).
[2] Screened interval of well in feet below ground surface.
[3] UA = Unconfined Aquifer
[4] Monitoring wells to be installed at locations shown on Fig. 7.

Table 4
Opinion of Probable Cost
(Capital Cost: Monitored Natural Attenuation Groundwater Sampling, One Event)

CAPITAL COST SUMMARY	Quantity	Unit	Unit Cost / Time	Extended Cost	Notes
Groundwater Monitoring					
Labor	1	ea	$9,000.00	$9,000	
Analytical Costs	1	ea	$14,000.00	$14,000	*VOC+Tot/Dis pb & cd + WQ = $500 ea * 28 wells*
Equipment/Expenses	1	ea	$3,112.00	$3,112	
			subtotal	**$26,112**	
		Remediation / Oversight Costs		**$26,112**	
Engineering and Related Costs					
Groundwater Evaluation/Reporting	1	ls	$5,000	$5,000	
Regulatory Interaction	5.00%	ls		$250	
Contingency	15.00%	%		$788	
Inflation (3 %, 0 years)	0.00%	%/yrs	1	$0	
			subtotal	**$6,038**	Expect to start in 2008
MNA Work Plan	1	ls	$0	$0	Costs included on Table 5
Regulatory Interaction	10.00%	ls		$0	Not Required
Contingency	0.00%	%		$0	
Inflation (3 %, 0 years)	3.00%	%/yrs	1	$0	
			subtotal	**$0**	
		Engineering and Related Costs		**$6,038**	
TOTAL				**$32,150**	

Notes: WQ = Water Quality Parameters

Table 5
Opinion of Probable Cost
(Present Worth: Monitored Natural Attenuation Groundwater Sampling for 30 Years)

Groundwater Monitoring Annual Cost	Qty	Unit	Unit Price	Inflation Rate*	Years of Inflation*	Extended Cost
Groundwater Monitoring Costs						
MNA Work Plan	1	one time only	$5,000	0.00%	0	$5,000
Groundwater Monitoring (quarterly)	4	event	$32,150	0.00%	0	$128,600
Groundwater Monitoring (semi-annual)	2	event	$32,150	0.00%	0	$64,300
Groundwater Monitoring (annual)	1	event	$32,150	0.00%	0	$32,150
						$230,050
Other						
Regulatory Interaction (work plan)	1	ls	$500	0.00%	0	$500
Regulatory Interaction (quarterly)**	4	ls	$3,215	0.00%	0	$12,860
Regulatory Interaction (semi-annual)**	2	ls	$3,215	0.00%	0	$6,430
Regulatory Interaction (annual)**	1	ls	$3,215	0.00%	0	$3,215
						$19,790
						$249,840

Present Worth Calculation		**Example**	**2008-2009 Mon.**	**2010-2012 Mon.**	**2013-2037 Mon.**
Annual Inflation Rate:		0.1 (10% inflation)	0.03	0.03	0.03
Discount or Interest Rate: (annual compounding)		0.08 (8% interest rate)	0.05	0.05	0.05
Annual Cost Throughout Current Year (cost of activities performed in current year not adjusted for inflation during current year)		$100 (Estimated 1998 cost)	$146,960	$70,730	$35,365
Current Year		2003	2007	2007	2007
Year of First End-of-Year Payment		2005	2008	2010	2013
Year of Last End-of-Year Payment		2013	2009	2012	2037
Present Worth (Beginning of Current Year)		$1,006	**$285,576**	**$196,503**	**$631,458**
TOTAL PRESENT WORTH	**$1,113,537**				

NOTES:

* If a unit rate is derived from a previous cost estimate, then it is adjusted for inflation to 2007 dollars. If the unit rate is based on current costs, then there is no adjustment for inflation.
** Estimated at 10% of One Monitoring Event cost.

Table 6
Treatability Study Data Summary for the April 2007 Monitoring Well Sampling
NL Industries Superfund Site
Pedricktown, New Jersey

	Well Number												
Parameter	**102***	**31**	**JDR**	**JS**	**23**	**OS**	**SS**	**SD**	**NS**	**KDR**	**KSR**	**11**	**34**
Inorganics													
Alkalinity (mg/L)	49	50	2	10	2	22	38	2	100	2	2	15	48
BOD (mg/L)	2	2	2	2	2	2	2	2	2	2	2	2	2
Chloride (mg/L)	4	4	7	3	7	6	43	3,000	2	49	3	37	44
COD (mg/L)	5	5	7	5	5	8	22	250	9	13	5	5	9
Calcium - dissolved (ug/L)	35,100	34,600	15,500	8,590	12,500	27,100	51,200	209,000	39,200	81,900	18,600	78,200	15,300
Calcium - total (ug/L)	38,200	31,300	11,800	8,370	11,600	24,700	47,500	199,000	36,700	78,600	16,500	72,200	14,000
Manganese - dissolved (ug/L)	81	61	437	30	675	231	516	8,170	7.0 J	3,830	110	2,210	2,580
Manganese - total (ug/L)	106	100	340	31	672	220	479	8,020	34	3,780	99	2,240	7,780
Iron - dissolved (ug/L)	709	474	1,890	267	114	7,710	23,400	294,000	18.8 U	77,500	18.8 U	18.8 U	27,500
Iron - total (ug/L)	3,150	2,910	2,700	736	344	7,830	23,200	287,000	1,420	76,300	423	19	N/A
Sulfate (mg/L)	46	41	220	17	210	220	110	9,800	41	4,600	86	780	16
Sulfide (mg/L)	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Organics													
TOC (mg/L)	3.12	3.11	3.76	2.56	1.37	4.46	11	26	4.9	4.06	1.56	0.4	5.19

J = Data indicates the presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater than zero. The concentration given is an approximate value.

U = Parameter was flagged in data validation because of laboratory contamination and are considered non-detects.

* 102 is a duplicate sample obtained from monitoring well 31.

N/A = Not Analyzed

ND = Non Detect

Table 7
Opinion of Probable Cost
(pH Adjustment, Reagent Injection and Injection Point Installation Capital Costs)

Capital Cost Summary	Quantity	Unit	Unit Cost / Time	Extended Cost	Notes
Remediation Costs					
Mobilization	1	ls	$2,000.00	$2,000	
Injection Pt Installation	12	ea	$3,000.00	$36,000	Average 20 feet deep
Reagent Injection Equipment	1	ls	$7,500.00	$7,500	tanks, tubing, pumps
pH Neutralization (one event)	1	ls	$2,000.00	$2,000	NaOH application (approx. 5,000 lbs)
Reagent Chemicals (quarterly for 1 year)	4	ea	$125,000.00	$500,000	cd vol = 25 mill gall/1000 gal * $5
Labor for reagent injection/pH neutralization	5	ea	$1,500.00	$7,500	2 people @ $150/hr, one 10 hr day
			subtotal	**$555,000**	
Oversight, Injection pt Installation	7	day	$1,000	$7,000	
Regulatory Interaction	10.00%	ls		$55,500	10% of Remediation subtotal.
			subtotal	**$62,500**	
Contingency	30.00%	%		$185,250	
Inflation (3 %, 1 years)	3.00%	%/yrs	1	$24,083	
			subtotal	**$209,333**	
	Remediation/Oversight Costs			**$826,833**	Expect to perform in 2008 to 2009
Engineering and Related Costs					
Pilot Study + Work Plan	1	ls	$50,000	$50,000	Expect to perform in 2008
Regulatory Interaction	10.00%	ls		$5,000	
Contingency	30.00%	ls		$16,500	
Inflation (3 %, 1 years)	3.00%	%/yrs	1	$2,145	
			subtotal	**$73,645**	
Remedial Action Plan	1	ls	$10,000	$10,000	Plan for implementation of alternative
Regulatory Interaction	10.00%	ls		$1,000	10% of plan cost.
Contingency	30.00%	%		$3,300	
Inflation (3 %, 1 years)	3.00%	%/yrs	1	$429	
			subtotal	**$14,729**	Expect to perform in 2008-2009
	Engineering and Related Costs			**$88,374**	
TOTAL				**$915,207**	

Table 8
Opinion of Probable Cost
(Present Worth: Reagent Injection)

Present Worth Calculation		**Example**	**2008 Eng.**	**2009 Rem/Ovst**
Annual Inflation Rate:		0.1 (10% inflation)	0.03	0.03
Discount or Interest Rate: (annual compounding)		0.08 (8% interest rate)	0.05	0.05
Annual Cost Throughout Current Year (cost of activities performed in current year not adjusted for inflation during current year)		$100 (Estimated 1998 cost)	$88,374	$826,833
Current Year		2003	2007	2007
Year of First End-of-Year Payment		2005	2008	2009
Year of Last End-of-Year Payment		2013	2008	2009
Present Worth (Beginning of Current Year)		$1,006	**$86,691**	**$795,635**
TOTAL PRESENT WORTH	**$882,325**			

NOTES:
* If a unit rate is derived from a previous cost estimate, then it is adjusted for inflation to 2007 dollars. If the unit rate is based on
** Estimated at 10% of Operation and Maintenance cost.

Table 9
Opinion of Probable Cost
(Capital Cost: Permeable Reaction Barrier Construction Costs)

CAPITAL COST SUMMARY	Quantity	Unit	Unit Cost / Time	Extended Cost	Notes
PRB Construction					
Labor	1	ea	$972,000.00	$972,000	Laborers, operators and supervisors
Equipment	1	ea	$500,750.00	$500,750	Approx. 150 days in construction
Materials	1	ea	$2,560,000.00	$2,560,000	Approx 71,000 CF of Apatite II = $1.35 million
Admin Requirements	1	ea	$508,000.00	$508,000	Includes Mob/Demob
			subtotal	**$4,540,750**	
		Remediation / Oversight Costs		**$4,540,750**	
Oversight Costs					
Construction Total	1	ls	$4,540,750	$4,540,750	Not included in estimate
Regulatory Interaction	5.00%	ls		$227,038	
Contingency	30.00%	%		$1,430,336	
Inflation (3 %, 1 years)	3.00%	%/yrs	0	$0	
			subtotal	**$6,198,124**	Expect to start in 2009
Remedy Design	1	ls	$50,000	$50,000	
Regulatory Interaction	5.00%	ls		$2,500	
Contingency	30.00%	%		$15,750	
Inflation (3 %, 0 years)	3.00%	%/yrs	0	$0	Costs provided in 2009 dollars
			subtotal	**$68,250**	
		Total		**$6,266,374**	

Table 10
ALTERNATIVE COMPARISON MATRIX
NL INDUSTRIES SITE, PEDRICKTOWN, NJ

	Remedial Alternatives				
Evaluation Criteria	**No Action**	**MNA**	**Reagent Injection**	**Permeable Reaction Barriers**	**Pump and Treat**
Overall Protection of Human Health and the Environment	Protective with application of institutional controls restricting groundwater access.	Same as no action.	Most protective alternative based upon relatively short projected period to achieve RAOs.	No more effective than no action.	No more effective than no action.
Compliance With ARARs	Compliant over long-term, assuming continuation of natural attenuation processes.	Same as no action.	Compliant with NJGQSs in short time frame (1-5 yrs). No other ARARs apply.	No more effective than no action.	No more effective than no action.
Long-Term Effectiveness and Permanence	Effective and permanent, assuming continuation of natural attenuation processes.	Same as no action.	Very effective and permanent.	No more effective than no action.	No more effective than no action.
Reduction of Toxicity, Mobilty and Volume	Acceptable over long-term. Constituents are not mobile. Volume reduction through natural attenuation.	Same as no action.	Will reduce toxicity and volume to negligible concern within approximately 5 year timeframe.	No more effective than no action.	No more effective than no action.
Short-Term Effectiveness	Poor short-term effectiveness.	Same as no action.	Effective	No more effective than no action.	No more effective than no action.
Implementability	Excellent	Excellent	Excellent. Will require pilot study to optimize and verify period to achive RAOs.	Can be constructed, but not effective.	System construction is feasible, but not effective.
Cost	Moderate costs associated with implementation of institutional controls and administrative costs.	Approx. $1,113,537 for thirty year monitoring program and work plan.	Approximately $882,325 plus groundwater monitoring costs (approx. $650,000 for 10 years).	Approximately $6,266,374 for construction of PRB + $2,000,000 for O&M every 3-5 years + groundwater monitoring for 30 years (approx. $1,100,000)	Cost estimated at $10.1 million in 1993 [O'Brien & Gere, 1993]. CSI currently estimates construction cost at approximately $3 million.
State/EPA Acceptance	Institutional controls for an extended period may be undesirable.	Becoming more widely accepted by regulators for inorganics in groundwater, institutional controls required.	Attainable assuming technical demonstration is favorable via pilot study.	Technology is widely accepted by regulatory community pending technical feasibilty.	Widely accepted by regulatory community and ROD prescribed remedy for groundwater.
Community Acceptance	Institutional controls for extended period may be undesirable.	Same as no action.	Acceptable to community for potential short cleanup time, minimal construction and no instit. Controls.	Extensive construction activity and poor effectiveness is not likely to be perceived favorably by local community.	Poor effectiveness compared to cost. Intrusive activitiy required is not likely to be perceived favorably by local community.

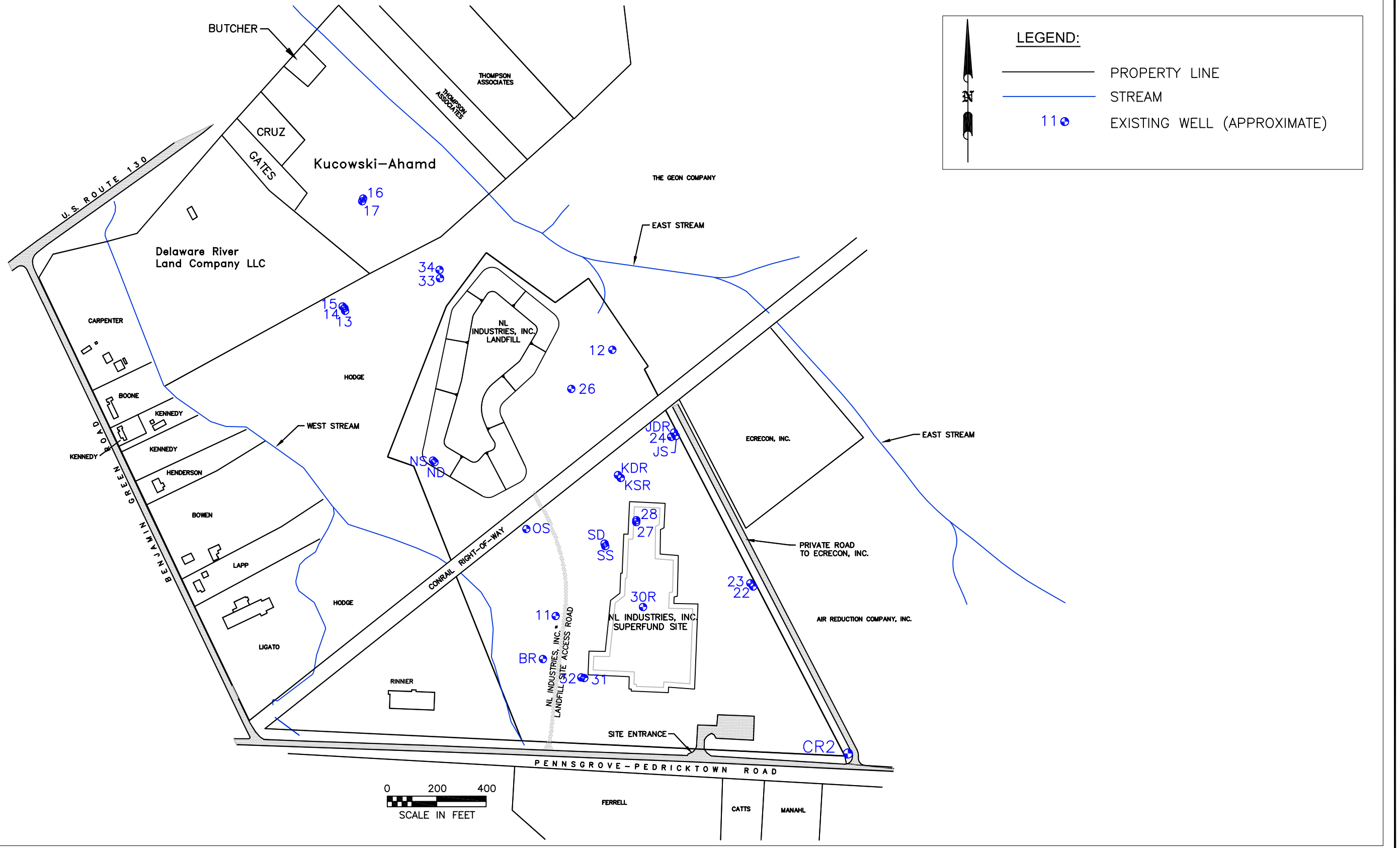
FIGURES

CSI Environmental, LLC
918 Chesapeake Ave.
Annapolis, MD 21403
410-268-2765

Site Location

NL Industries Superfund Site
Pedricktown, NJ

FIGURE
1



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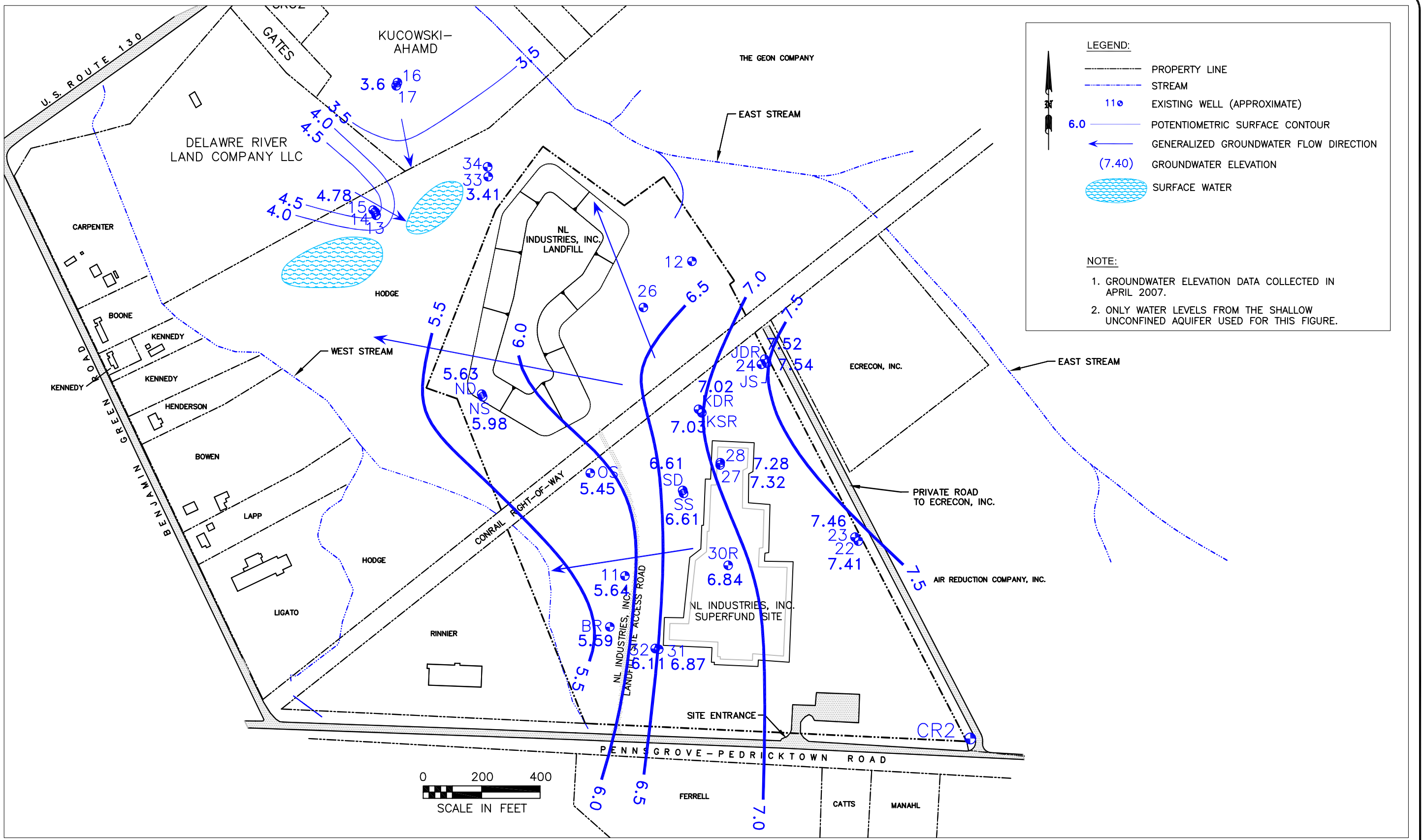
410–268–2765

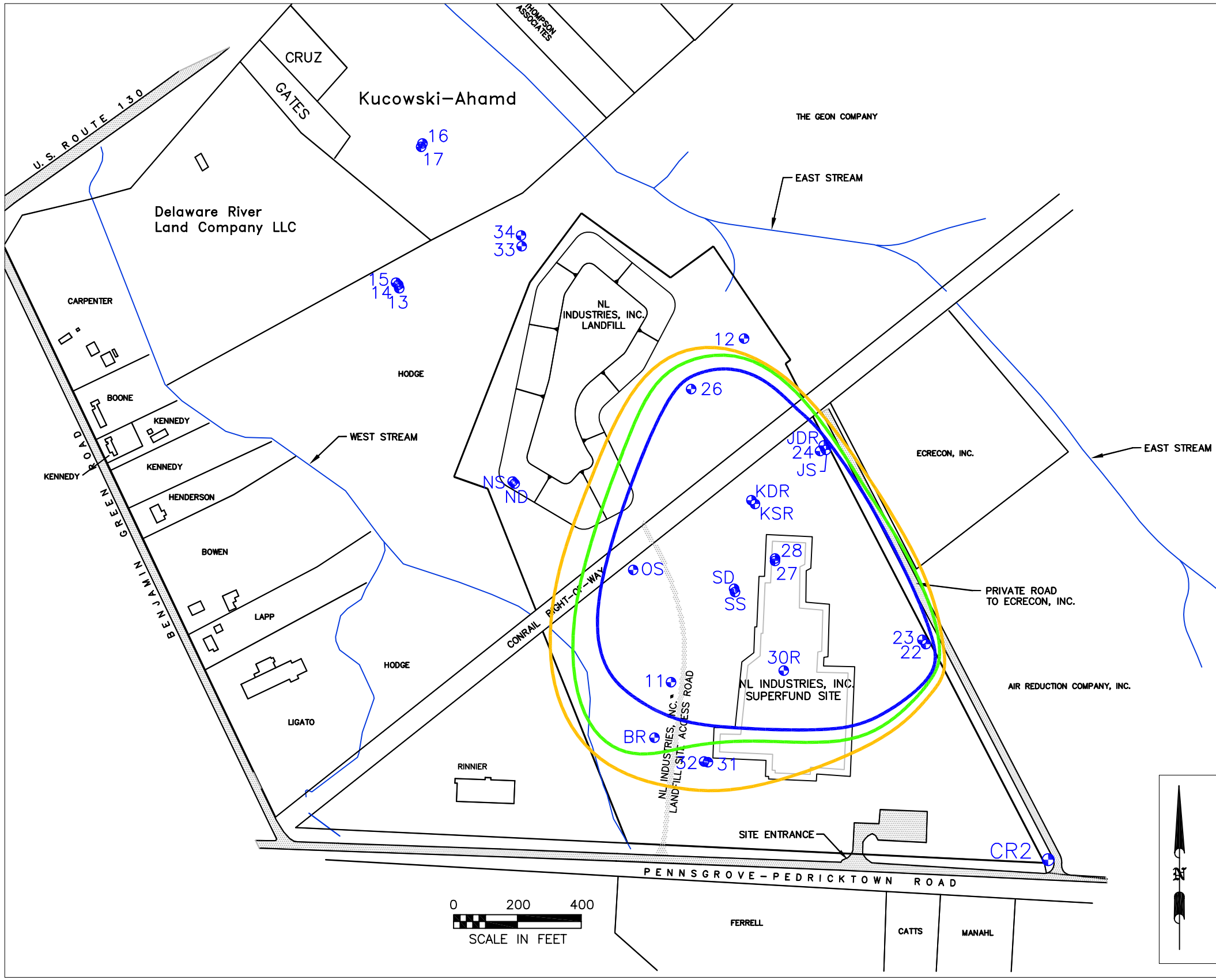
Site Overview

NL Industries Superfund Site
Pedricktown, NJ

FIGURE
2



CSI Environmental, LLC 918 Chesapeake Ave. Annapolis, MD 21403 410–268–2765		Groundwater Elevations and Inferred Flow Direction, April 2007 NL Industries Superfund Site Pedricktown, NJ	FIGURE 3



NOTES:

- In datasets that lacked total Cd concentration, dissolved concentration was substituted.
- Detections in which total Cd concentrations were not supported by dissolved Cd concentrations were not presented herein.
- 1983 data not shown because samples were not analyzed for Cd that year.
- 2004 data not shown. Below freezing temperatures during sampling event are believed to have affected data quality.

Cd detections above 4.0 ug/L

- 1988
- 1998
- 2007

LEGEND:

- PROPERTY LINE
- STREAM
- 11 EXISTING WELL (APPROXIMATE)

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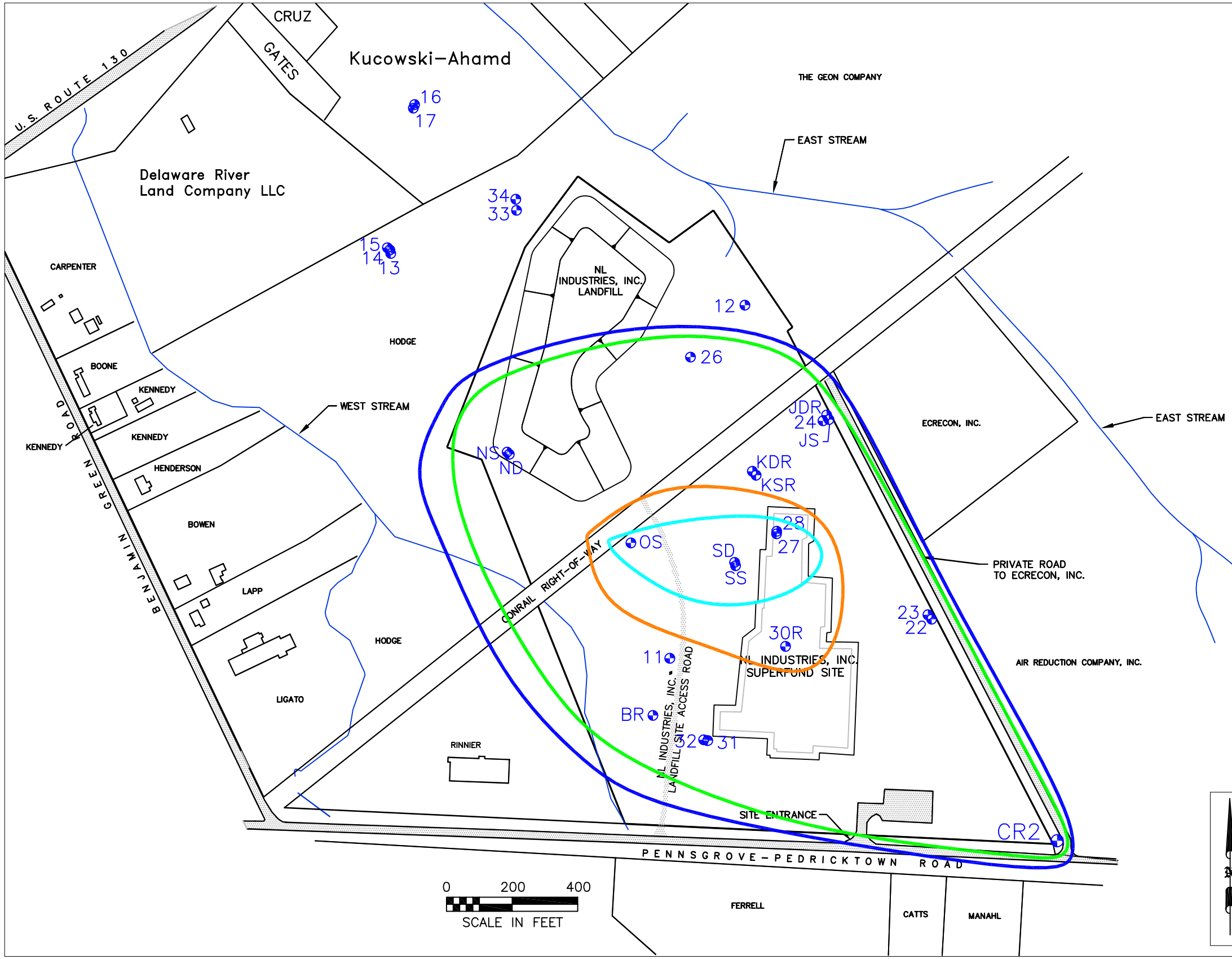
Data Source:

- CSI Environmental – Groundwater Monitoring Report
- GeoSyntec Phase II Technical Memorandum (2000)
- O'Brian & Gere Remedial Investigation (1990)

Historical Extent of Cd Concentrations in Groundwater Greater Than New Jersey Groundwater Quality Standard

NL Industries Superfund Site
Pedricktown, NJ

FIGURE
4



CSI Environmental, LLC
918 Chesapeake Ave.
Annapolis, MD 21403
410–268–2765

Data Source:
- CSI Environmental – Groundwater Monitoring Report
- GeoSyntec Phase II Technical Memorandum (2000)
- O'Brian & Gere Remedial Investigation (1990)

Historical Extent of Pb Concentrations in Groundwater Greater Than New Jersey Groundwater Quality Standard

NL Industries Superfund Site
Pedricktown, NJ

FIGURE
5

34	33
Cd – ND Cd(dis) – ND Pb – 16.3 Pb(dis) – ND	Cd – 3.0 J Cd(dis) – ND Pb – ND Pb(dis) – ND

13, 14, & 15
Cd – ND Cd(dis) – ND Pb – ND Pb(dis) – ND

ND	NS
Cd – ND Cd(dis) – ND Pb – 22.2 J Pb(dis) – ND	Cd – 1.5 U Cd(dis) – 1.4U Pb – 41.6 J Pb(dis) – ND

OS
Cd – 3.9J Cd(dis) – 4.2J Pb – 388 Pb(dis) – 320

SD	SS
Cd – 149J Cd(dis) – 156J Pb – 31 Pb(dis) – 90.4	Cd – 10.6J Cd(dis) –11.8J Pb – 82.9 Pb(dis) – 13

30R
Cd – 163J Cd(dis) – 169J Pb – ND Pb(dis) – 1.6J

11
Cd – 110J Cd(dis) – 113J Pb – ND Pb(dis) – ND

BR
Cd – ND Cd(dis) – 1.1U Pb – ND Pb(dis) – ND

31	32
Cd – 1.5J Cd(dis) – 1J Pb – 20.6J Pb(dis) – ND	Cd – ND Cd(dis) – ND Pb – ND Pb(dis) – ND

16	17
Cd – ND Cd(dis) – ND Pb – ND Pb(dis) – ND	Cd – ND Cd(dis) – ND Pb – ND Pb(dis) – ND

12
Cd – ND Cd(dis) – ND Pb – ND Pb(dis) – ND

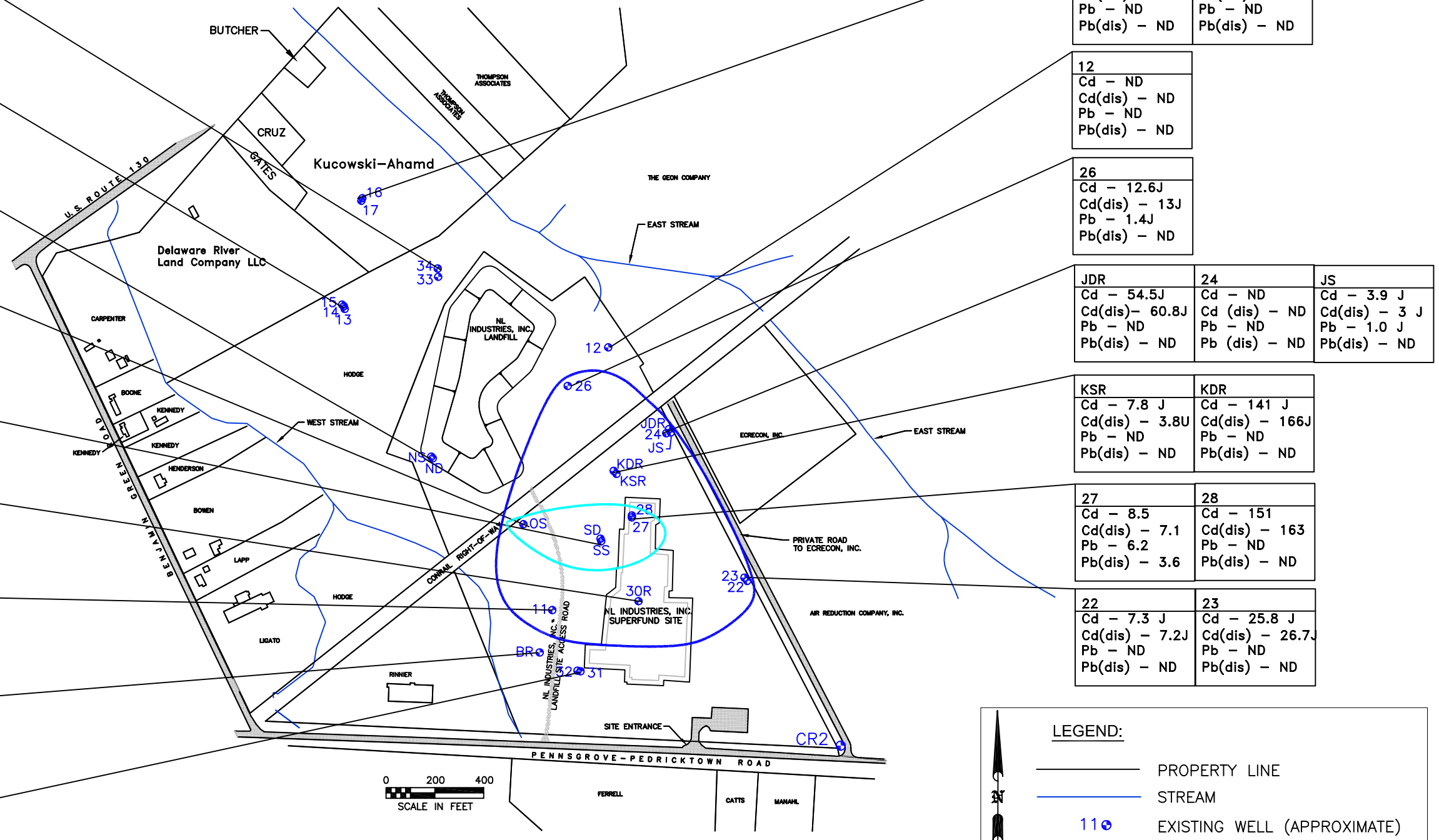
26
Cd – 12.6J Cd(dis) – 13J Pb – 1.4J Pb(dis) – ND

JDR	24	JS
Cd – 54.5J Cd(dis)– 60.8J Pb – ND Pb(dis) – ND	Cd – ND Cd (dis) – ND Pb – ND Pb (dis) – ND	Cd – 3.9 J Cd(dis) – 3 J Pb – 1.0 J Pb(dis) – ND

KSR	KDR
Cd – 7.8 J Cd(dis) – 3.8U Pb – ND Pb(dis) – ND	Cd – 141 J Cd(dis) – 166J Pb – ND Pb(dis) – ND

27	28
Cd – 8.5 Cd(dis) – 7.1 Pb – 6.2 Pb(dis) – 3.6	Cd – 151 Cd(dis) – 163 Pb – ND Pb(dis) – ND

22	23
Cd – 7.3 J Cd(dis) – 7.2J Pb – ND Pb(dis) – ND	Cd – 25.8 J Cd(dis) – 26.7J Pb – ND Pb(dis) – ND



LEGEND:

- PROPERTY LINE
- STREAM
- 11 EXISTING WELL (APPROXIMATE)
- AREA OF INTEREST FOR Pb
- AREA OF INTEREST FOR Cd

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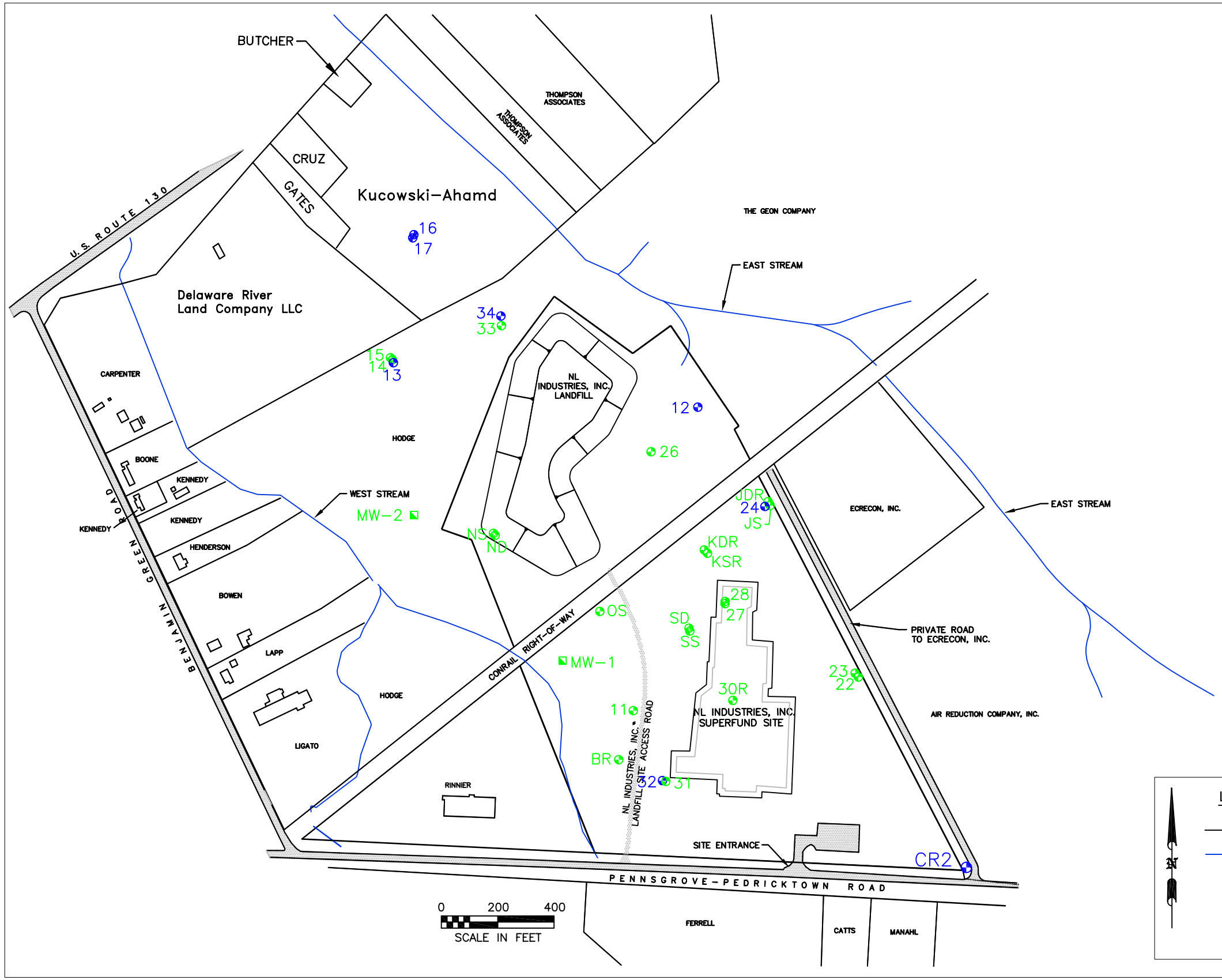
410–268–2765

Data Source:
CSI Environmental – NL Groundwater Report 2007

Cd & Pb Concentrations in Groundwater April, 2007

NL Industries Superfund Site
Pedricktown, NJ

FIGURE 6



Proposed Wells for Use in MNA Alternative

Monitoring Well	Well Depth (1)	Screened Interval (2)	Aquifer Zone (5)	Rationale
BR	39	33-39	UA	western limits
JS	15.37	5-15	UA	eastern limits
JDR	27.26	17-27	UA	eastern limits
KSR	15	5-15	UA	central area
KDR	24	14-24	UA	central area
NS	16.5	6.5-16.5	UA	western limits
ND	24	14-24	UA	western limits
OS	21.3	6.3-21.3	UA	western limits
SS	16.4	6.4-16.4	UA	central area
SD	29.4	17.4-29.4	UA	central area
11	54.1	34.1-54.1	UA	western limits
22	16	11-16	UA	eastern limits
23	24	24-34	UA	eastern limits
26	22	12-22	UA	northern limts
27	15	5-15	UA	central area
28	30	20-30	UA	central area
30R	28.71	17-27	UA	central area
31	15	5-15	UA	southern limits
33	10	5-10	UA	northern limts
14	46.6	26.6-46.6	UA	northern limits
15	25	10–25	UA	northern limits

LEGEND:

- PROPERTY LINE
- STREAM
- 13 — NON–MNA WELL
- 11 — EXISTING MNA WELL
- MW–1 — PROPOSED NEW MNA WELL LOCATION

N

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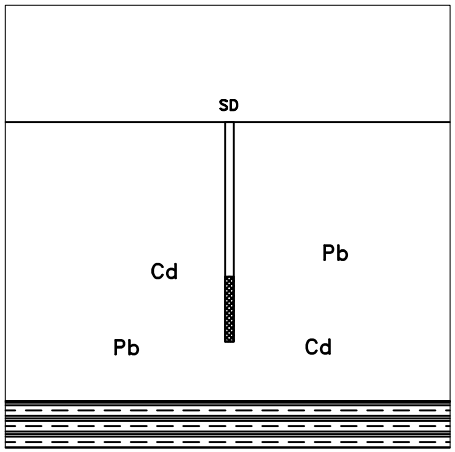
Proposed Locations for Monitored Natural Attenuation Ground Water Monitoring

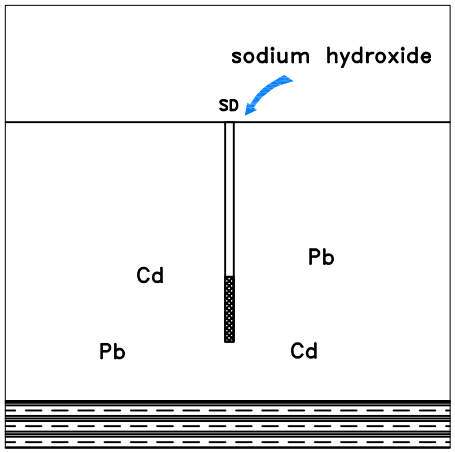
NL Industries Superfund Site
Pedricktown, NJ

FIGURE
7

Before reagent Injection
- Cd concentration = 149 ppb
- Pb concentration = 31 ppb
- PH = 3.08



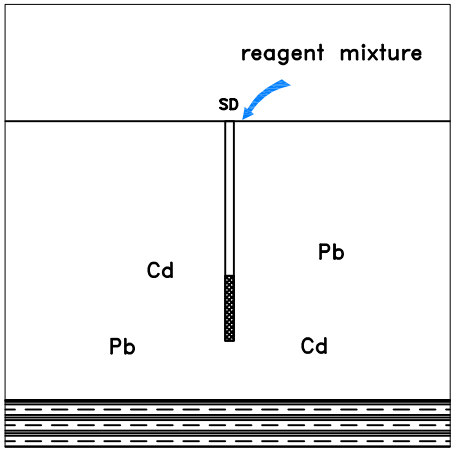
Before reagent injection



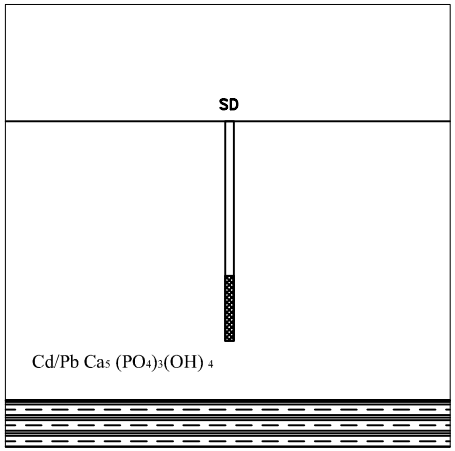
Stage 1 – PH Adjustment

Stage 1 – Adjust PH
- An alkaline PH is necessary to stimulate metal phosphate formation. A 5% sodium hydroxide solution is introduced to adjust the well's PH to approximately 8.5.

Stage 2 – Reagent Injection
- Mixture of sodium tri–polyphosphate and calcium chloride added to well.



Stage 2 – Reagent Injection



After reagent Injection

After Reagent Injection
- Cd & Pb ground water concentrations not detected after reagent injection.
- Cd & Pb form metal phosphates ($Cd/PbCa_5(PO_4)_3(OH)_4$) becoming insoluble & inert.

CSI Environmental, LLC
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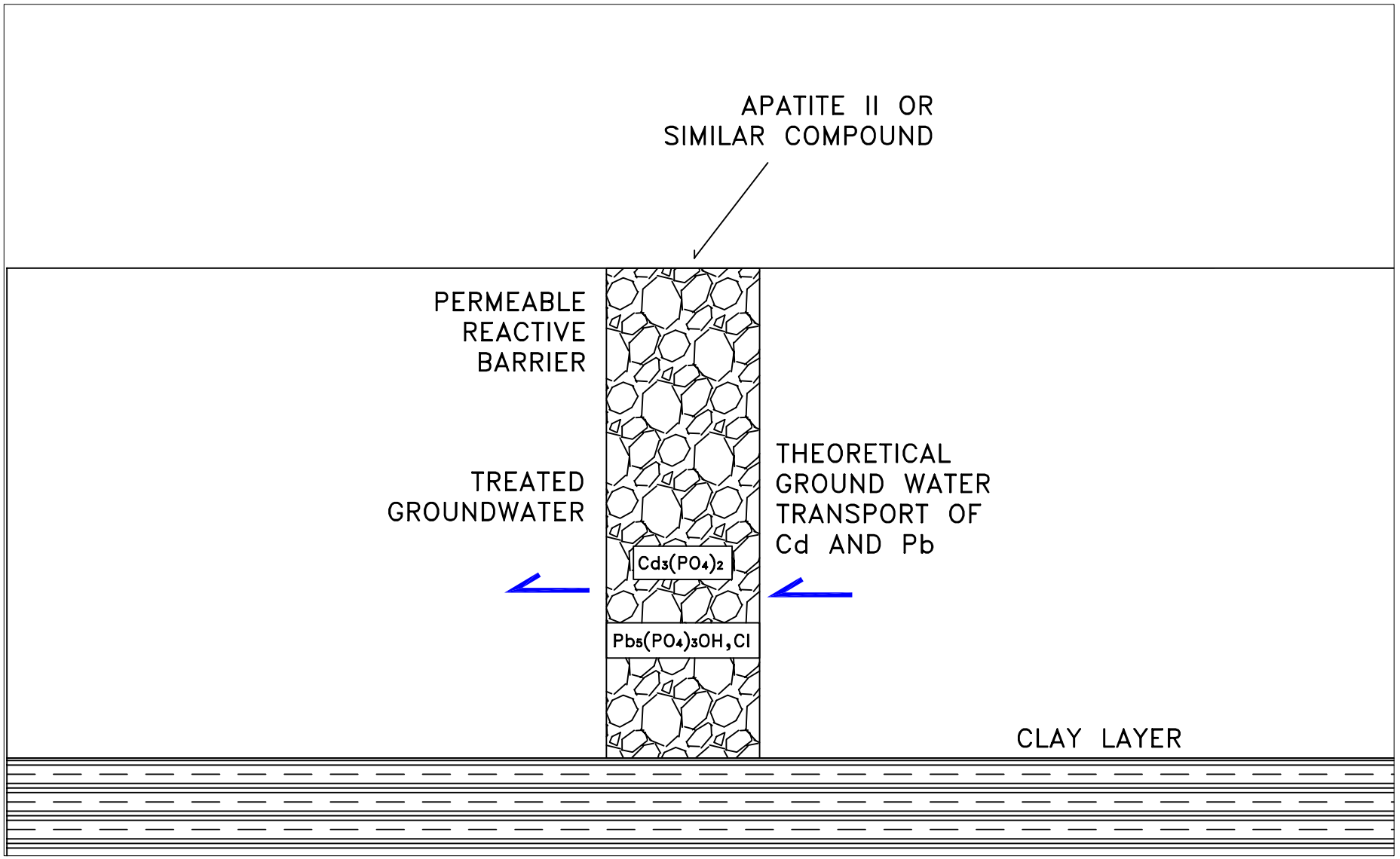
410–268–2765

Data based on bench scale treatability study by Water Remediation Services, Inc (2007).

Conceptual Application of Reagent Injection Alternative

FIGURE 8



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Annapolis, MD 21403
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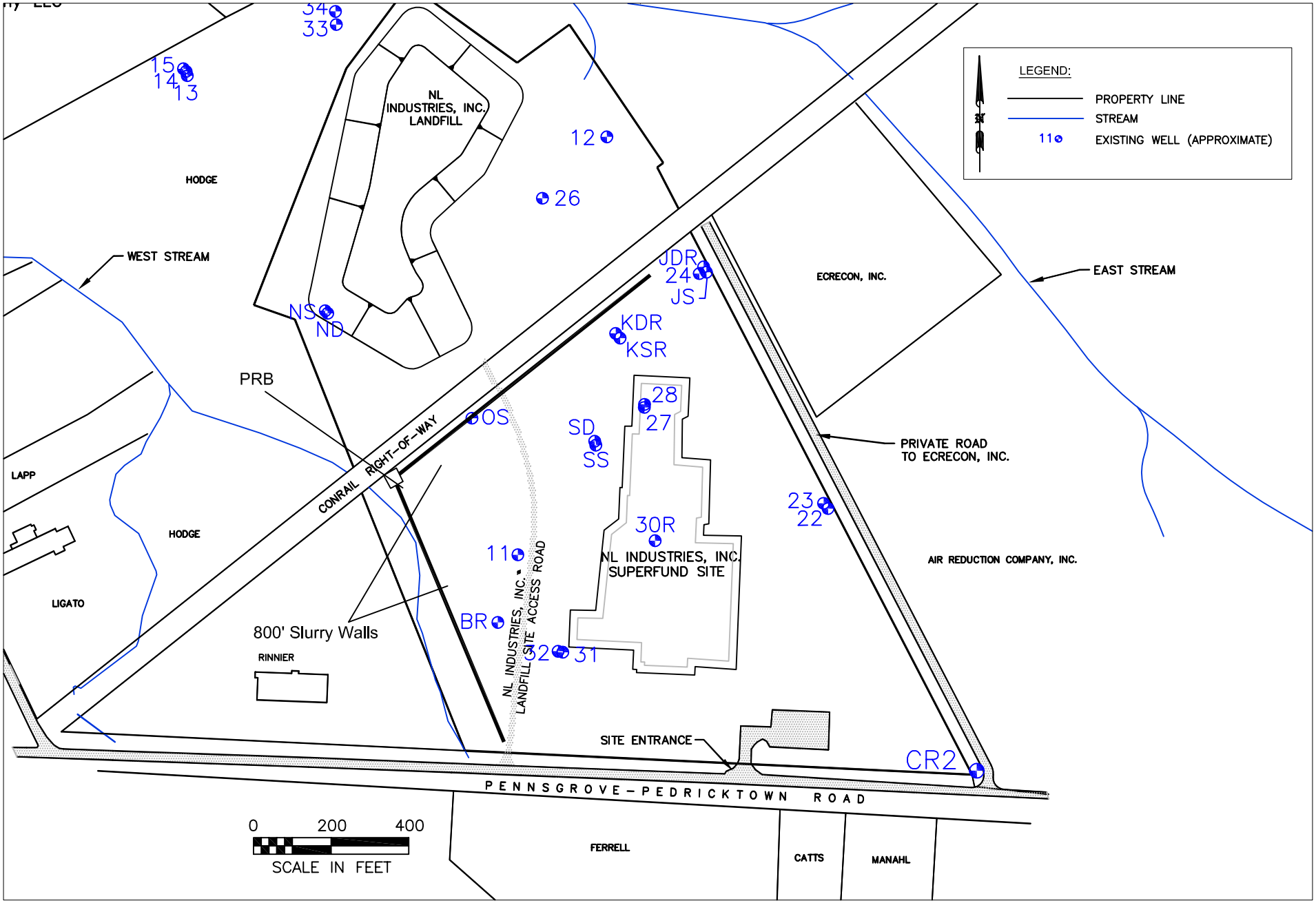
Cross Section View Of
Permeable Reactive Barrier

FIGURE
9



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Conceptual PRB & Containment Wall Location

NL Industries Superfund Site
Pedricktown, NJ

FIGURE 10

APPENDIX A
Table F from 1994 Record of Decision

TABLE F
NL INDUSTRIES SITE
GROUND WATER ARARS

HAZARDOUS CONTAMINANT	NJMCL[1]	NJGWQS[2]	PQL[3]	MCL[4]
Organic (ppb)				
Acetone	-	700	NA	-
Bis-(2-ethylhexyl)phthalate	4	3	30	-
Chloroform	-	6	1	-
1,2-Dibromomethane	-	-	-	-
1,1-Dichloroethane	-	70	-	-
1,1-Dichloroethylene	2	1	2	7
1,2-Dichloropropane	5	0.5	1	5
Ethylbenzene	700	700	5	700
Naphthalene	-	-	-	-
N-Nitroso-di-n-propylamine	-	0.005	20	-
Tetrachloroethylene	1	0.4	1	5
Toluene	1,000	1,000	5	1,000
1,1,1-Trichloroethane	26	30	1	200
1,2,4-Trimethylbenzene	-	-	-	-
1,3,5-Trimethylbenzene	-	-	-	-
Vinyl Chloride	2	0.08	5	2
Xylene(s) (total)	44	40	2	10,000
o-		NA	1	-
m&p-		NA	2	

[1]New Jersey Maximum Contaminant Levels (NJMCLs) are expressed in ppb. (N.J.A.C 7:10-16.7) For any listed contaminant, the more stringent of the NJMCL, NJGWQS, or federal MCL applies.

[2]New Jersey Ground Water Quality Standards (NJGWQS) (N.J.A.C. 7:9-6) are expressed in parts per billion (ppb).

[3] The Practical Quantitation Levels (PQLs) are expressed in ppb. In accordance with N.J.A.C. 7:9-6.9(c), where a constituent standard (the criterion adjusted by the antidegredation policy and applicable criteria exemptions) is of a lower concentration than the relevant PQL, the Department shall not (in the context of an applicable regulatory program) consider the discharge to be causing a contravention of that constituent standard so long as the concentration of the constituent in the affected ground water is less than the relevant PQL.

[4]Federal Maximum Contaminant Levels (MCLs) are expressed in ppb. For any listed contaminant, the more stringent of the federal MCL, NJMCL, and the NJGWQS applies.

TABLE F (Cont'd)
NL INDUSTRIES SITE
GROUND WATER ARARS

HAZARDOUS CONTAMINANT	NJMCL[1]	NJGWQS[2]	PQL[3]	MCL[4]
Metals (ppb)				
Antimony	6	2	20	6
Arsenic (total)	50	0.02	8	50
Beryllium	4	0.008	20	4
Cadmium	5	4	2	5
Chromium (total)	100	100	10	100
Copper	1,300*	1,000	1,000	-
Cyanide	200	200	40	200
Lead (total)	15*	5	10	-
Mercury (total)	2	2	0.5	2
Nickel (soluble salts)	100	100	10	100
Selenium (total)	50	50	10	50
Silver	-	NA	2	-
Thallium	2	0.5	10	2
Zinc	-	5,000	30	-
Radiation (see footnotes 4 & 5 for units)				
Gross Alpha	15[5]	15[5]	-	15[5]
Gross Beta	4[6]	4[6]	-	4[6]

* New Jersey Action Level

[5]Federal MCL expressed in picocuries/liter (pC/l). From 40 CFR part 141.

[6]Federal MCL expressed in picocuries/liter (pC/l). From 40 CFR part 141.

APPENDIX B

Core Laboratory Report (Thin Section Petrography and X-Ray Diffraction, October 1998)

CORE LABORATORIES

PETROGRAPHIC ANALYSES

FOR

GEOSYNTEC CONSULTANTS
SOIL SAMPLES
NL INDUSTRIES PROJECT

File 198178
October 1998

Performed by:
Core Laboratories, Advanced Technology Center
Reservoir Geology/Stratigraphy Group
1875 Monetary Lane
Carrollton, Texas 75006
U.S.A.
(972) 466-2673

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CORELAB

PETROLEUM SERVICES

October 29, 1998

Jeff Moore
GeoSyntec Consultants
10015 Old Columbia Rd., Ste. A-200
Columbia, Maryland 21046

Subject:	**Petrographic Analyses**
Sample Type:	**Sand Soils**
Location:	**NL Industries, Pedricktown, New Jersey**
File Number:	**198178**

Dear Mr. Moore:

The enclosed study includes detailed thin section petrography and X-ray diffraction (XRD) analyses of four soil samples from NL Industries, Pedricktown, New Jersey. The main focus of this report is to document the presence or absence of any mineral matrices in the samples that may contain lead-bearing substances. A secondary focus of the report is to document the possible detection of lead-bearing substances. Table 1 shows the XRD data, and Table 2 contains the point-count results. Plates 1 through 4 display the thin section photomicrographs and descriptions. Two original copies of this report were prepared. You have received one report, and the other was sent to your colleague, Hal Tuchfeld, in California.

Thank you for selecting Core Laboratories to perform these analyses for GeoSyntec Consultants. Please feel free to contact us if you have any questions or comments concerning this report, or if we can be of further service.

Sincerely,

Drew L. Dickert

Drew L. Dickert
Senior Petrologist
Reservoir Geology/Stratigraphy Group
(972) 323-3998

PROJECT TEAM

Drew L. Dickert
Senior Petrologist

Malcolm S. Jones
X-ray Diffraction Specialist

Mark A. Smesny
Thin Section Preparation

Donald G. Harville
Supervisor/Reviewer

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THIN SECTION PHOTOMICROGRAPHS AND DESCRIPTIONS

PLATE 1: Sample SV26072098; Depth 14 – 16 feet
PLATE 2: Sample SV28071698; Depth 12 – 16 feet
PLATE 3: Sample SV29071598; Depth 10 – 16 feet
PLATE 4: Sample SV40; Depth N.A.

DISCUSSION

Introduction

Core Laboratories' Reservoir Geology/Stratigraphy Group, Carrollton, Texas, performed a petrographic study on four soil samples from NL Industries, Pedricktown, New Jersey. The analyses performed were detailed thin section petrography (includes a point-count of 250 points) and bulk & clay X-ray diffraction (XRD). The purposes of this study are to describe the natural soil texture and composition, document the presence or absence of any mineral matrices in the samples that may contain lead-bearing substances, and identify any lead-bearing substances, if possible. Table 1 shows the XRD data, and Table 2 contains the point-count results. Plates 1 through 4 display the thin section photomicrographs and descriptions. The following discussion summarizes the findings. For ease of reference in the discussion, the sample names have been shortened to SV26, SV28, SV29, and SV40.

Sample Descriptions

The thin section analysis shows that all four soil samples are poorly sorted sands. SV26, SV28, and SV40 are silty sands, in which at least ten percent of the grains are silt sized. SV29 is a muddy sand, where clay matrix and silt together compose over ten percent of the sample. The muddy sand has the finest estimated average grain size (0.28 mm, excluding clay matrix), whereas the other sands have estimated average grain sizes between 0.36 and 0.40 millimeters. Most of the grains in each sample range from <0.01 to 2.5 millimeters in diameter. No pebbles (grains >4 mm) are present in the thin sections; however, traces of pebbles were noted in the jars containing SV26 and SV28, and minor amounts of pebbles in the SV40 sample jar. The individual grain shapes in each sample range from rounded to angular. Subrounded and subangular grains are predominant. Angular grains are mostly concentrated in the finer grain size fractions. Samples SV29 and SV40 seem to contain greater amounts of rounded grains than the other two samples. Grain compaction and natural pore systems could not be assessed, because these sands are unconsolidated and disaggregated in the thin sections. The uneven distribution of silt, clays, and heavy minerals in SV26, SV28, and SV40 could be wholly the result of sample preparation, or it may indicate the presence of some disrupted lamination.

The soil composition was measured two different ways. XRD analysis (Table 1) shows that three of the samples (SV 26, SV28, and SV40) contain 96 to 99 percent quartz, with small amounts of feldspars and clays. Sample SV29 contains only 83 percent quartz by XRD, with 11 percent clays and 5 percent feldspars. Point-count analysis (Table 2) shows similar proportions of quartz, feldspars, and clays, compared to Table 1. Most of the quartz occurs as individual mono- and poly-crystalline grains. The minor metamorphic rock fragments (0.4 – 2.4%) are mostly metaquartzites. Traces of quartz overgrowth cement are found on some grains (Plate 1B). Some of these overgrowths probably formed in-situ, but others may be relics from a recycled sandstone source. Small amounts of heavy minerals (magnetite/ilmenite, tourmaline, zircon, hornblende, etc.) and glauconite grains are also found in every sample. The muddy sand (SV29, Plate 3) contains common clay matrix. Samples SV28 and SV40 contain minor amounts of clay matrix, 2 percent and 3 percent by XRD, respectively. The thin

sections also reveal a little more clay in SV40 than SV28, although this is not reflected in the point-count results because of the highly uneven distribution of clays in SV40. The clay minerals are mostly detrital, but they appear to be partially altered and recrystallized. XRD results reveal that the clay fractions consist of 60 to 78 percent kaolinite and 22 to 40 percent illite/mica (includes sericite). Tiny crystals and coatings of iron oxide and titanium oxide represent 1.2 to 4.0 percent of the thin sections by point-count. Traces of organic grain coatings are present in one sample (SV29). Rare amounts of dolomite occur within a few quartz grains (SV26 and SV28). XRD detected possible traces of lead phosphate in SV28 and SV40.

Conclusions

The main purpose of this study was to document the presence or absence of any mineral matrices that may contain lead compounds that could be interpreted to be contaminants from the seeping of lead-bearing fluids into the soil. As a secondary purpose, any lead-bearing substances detected were to be identified.

Some of the quartz and feldspar grains show signs of leaching (pitted grains; Plates 1A & 4A), but this can be present in natural soils and does not necessarily indicate damage from contaminating fluids. The thin sections reveal no mineral grains or crusts that are composed principally of lead compounds. Using polarized and reflected light microscopy, the minor amounts of dark coatings on grains and tiny crystals in the clay matrix (Plates 1-4B) are identified as mostly iron and titanium oxides. Many of these crystals are so small (<1-3 microns) that they cannot be adequately identified in thin section. If any lead compounds or elemental lead are present, they should be associated with these tiny crystals and the oxide coatings. Clay aggregates of kaolinite and illite/mica may be able to adsorb lead onto the clay crystal surfaces; however, these clay types are not noted for absorption of elements into their crystal structures.

The traces of lead phosphate reported by XRD in SV28 and SV40 are based on one peak in the diffraction pattern matching the primary peak for lead phosphate. In XRD analysis, separate mineral phases are recognized by distinct diffraction patterns containing a primary peak and secondary peaks for each mineral. The secondary peaks of some minerals can overlap primary peaks of other minerals. Also, relative peak heights are related to mineral concentration, and the secondary peaks for minerals present in small quantities are not generally detectable. Even the primary peaks for trace minerals are sometimes difficult to resolve from background noise. The peak identified to be a primary peak for lead phosphate does not seem to correspond to a secondary peak of any other component in the sample (if it did, the interpretation of lead phosphate would not be justified). Thus, the presence of small amounts of lead phosphate is a possibility, even though a distinct diffraction pattern for this compound is lacking (no secondary peaks). If lead phosphate is indeed present, one would expect it to be most prevalent in SV29, where clay matrix and iron and titanium oxide coatings are most common, but XRD does not show traces of lead phosphate for this sample.

This thin section and XRD study shows that mineral matrices that may contain lead-bearing substances are present. However, lead compounds, if present, are rare in these soil samples. These analyses are not sufficiently sensitive to completely affirm or deny the presence of rare amounts of lead in these samples.

ANALYTICAL PROCEDURES

Thin Section Preparation

Sample fractions are prepared for thin section analysis by first impregnating them with epoxy to augment sample cohesion and to prevent loss of materials during grinding. A blue dye was added to the epoxy to highlight the pore spaces. Each sample was mounted on a frosted glass slide and then cut and ground in water to an approximate thickness of 30 microns. The thin sections were examined using standard petrographic techniques.

X-ray Diffraction Analysis

X-ray diffraction analysis provides the identification and quantification of the rock-forming minerals present in the formation. Samples selected for bulk and clay X-ray diffraction analysis were dried and cleaned of obvious contaminants. Each sample was dried, weighed, placed in water and treated with a sonic cell disrupter. The resultant slurries were centrifuged to fractionate each fraction at 4 microns. The suspended <4 micron fraction was decanted and saved. The >4 micron fraction was dried and weighed to determine the percent of clay- and silt-sized materials. The suspended <4 micron fraction was suctioned onto a pure silver substrate to orient the clay-sized particles. The <4 micron fraction was analyzed in an air-dried state and then treated with ethylene glycol vapor for 24 hours and re-analyzed. The >4 micron fraction was milled and scanned on an X-ray diffractometer. The samples selected for bulk analysis only were also milled and scanned on the diffractometer. The resulting diffractograms were then analyzed for mineral content using a profile-fitting algorithm. The integrated areas from the profile-fitting algorithm were entered into a spreadsheet that contains correction coefficients for numerous minerals. These coefficients were obtained according to the adiabatic method outlined by Chung (1974a, 1974b, 1974c). The tabular data are reported in a weight percent format in Table 1.

REFERENCES

Chung, F.H. (1974) A new X-ray diffraction method for quantitative multicomponent analysis. Advances in X-ray Analysis, 17, 106-115.

Chung, F.H. (1974) Quantitative interpretation of X-ray diffraction patterns of mixtures. I. Matrix-flushing method for quantitative multicomponent analysis. Journal of Applied Crystallography, 7, 519-525.

Chung, F.H. (1974) Quantitative interpretation of X-ray diffraction patterns of mixtures. II. Adiabatic principle of X-ray diffraction analysis of mixtures. Journal of Applied Crystallography, 7, 526-531.

Folk, R.L. (1980) Petrology of Sedimentary Rocks. Hemphill Publishing Company, Austin, Texas, 184p.

Sample ID	Depth	Whole Rock Composition (weight %) Quartz	K feldspar	Plagioclase	Calcite	Dolomite	Siderite	Pyrite	Pb phosphate	Hematite	*Total Clays*	Relative Clay Abundance (Normalized to 100%) Illite/Mica	Kaolinite	Chlorite	Smectite	Illite/ Smectite
SV26 7/20/98	**14-16**	99	0	Tr	0	Tr	0	0	0	0	*1*	31	69	0	0	0
SV28 7/16/98	**12-16**	96	1	1	0	Tr	0	0	Tr	0	*2*	40	60	0	0	0
SV29 7/15/98	**10-16**	83	3	2	0	1	0	0	0	Tr	*11*	22	78	0	0	0
SV-40	**N/A**	96	0	Tr	0	1	0	0	Tr	0	*3*	36	64	0	0	0

CORE LABORATORIES

Point-Count Tally Sheet

GeoSyntec Consultants
Sand Soil Samples
NL Industries Project

C.L. File No: 198178
Date: 27-Oct-98
Petrologist: D. Dickert

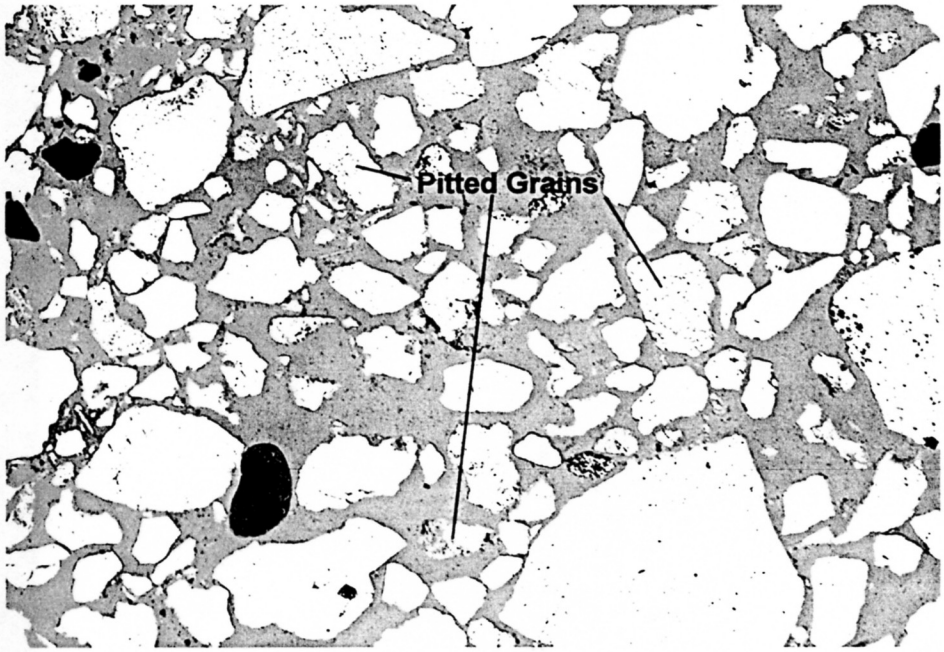
Table 2
Modal Percent

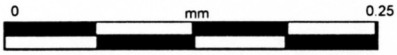
Sample ID		SV26	SV28	SV29	SV40
Quartz:	Monocrystalline	74.0	80.8	61.6	76.0
	Polycrystalline	17.6	10.8	7.2	17.2
	Total	**91.6**	**91.6**	**68.8**	**93.2**
Feldspars:	K-Feldspar	0.4	0.8	2.4	1.2
	Plagioclase	tr	tr	1.6	tr
	Total	**0.4**	**0.8**	**4.0**	**1.2**
Rock	Crystalline Igneous		tr	0.8	tr
Fragments:	Sedimentary	0.4	tr	4.0	0.4
	Metamorphic	1.2	0.8	2.4	0.4
	Chert/Chalcedony	tr	1.2	0.4	0.4
	Total	**1.6**	**2.0**	**7.6**	**1.2**
Accessory:	Biotite	tr		tr	tr
	Muscovite	tr	tr	1.6	tr
	Magnetite/Ilmenite	1.2	tr	0.4	0.4
	Tourmaline	0.4	tr	0.4	tr
	Zircon	tr	0.4	tr	tr
	Hornblende	tr	tr	0.4	tr
	Sphene	0.4		tr	
	Other Heavy Minerals	tr	tr	0.4	tr
	Glauconite	0.8	tr	0.4	tr
	Organic Debris	tr			
	Total	**2.8**	**0.4**	**3.6**	**0.4**
Matrix:	Detrital Clay	0.4	2.8	10.8	2.4
	Pseudomatrix				
	Total	**0.4**	**2.8**	**10.8**	**2.4**
Clays:	Kaolinite	tr	tr		tr
(Authigenic)	Chlorite		tr	tr	tr
	Sericite	tr	tr	tr	tr
	Undiff. Illite/Smectite	0.8	0.4	tr	0.4
	Total	**0.8**	**0.4**		**0.4**
Non-Clay	Quartz Overgrowths	0.8	0.4	0.8	tr
Cements:	Feldspar Overgrowths				
	Dolomite	tr	tr		
	Pyrite				
	Iron Oxide	0.8	0.4	2.4	tr
	Titanium Oxide	0.8	1.2	1.6	1.2
	Organic Coatings			0.4	
	Total	**2.4**	**2.0**	**5.2**	**1.2**
Porosity:	Not counted - disaggregated samples				
	Total				
Grand Total		**100.0**	**100.0**	**100.0**	**100.0**

THIN SECTION PETROGRAPHY

31X

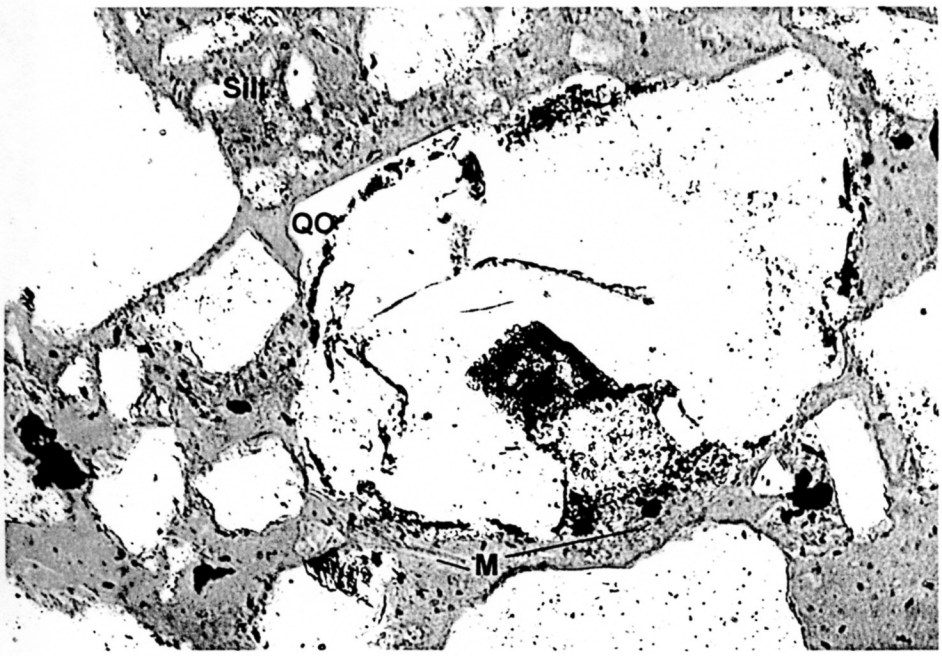
Plate 1A





200X

Plate 1B



GeoSyntec Consultants
Soil Samples
NL Industries Project
Sample: SV26072098
Depth: 14 - 16 feet

Soil Type & Texture

Classification (Folk)	Silty sand
Grain Size (mm)	Range = <0.01 - 2.54
(estimated)	Avg. = 0.40 (med. sand)
Grain Sorting	Poor
Grain Roundness	Rounded to angular
Compaction	Disaggregated
Structures	None evident

Composition (%)

Detrital Grains		**Detrital Matrix**	
Mono. Qtz.	74.0	Clay	0.4
Poly. Qtz.	17.6	**Authigenic Clay**	
K-feldspar	0.4	Kaolinite	tr
Plagioclase	tr	Chlorite	
Igneous R.F.		Sericite	tr
Sedim. R.F.	0.4	Undiff. I/S	0.8
Meta. R.F.	1.2	**Cements (non-clay)**	
Chert	tr	Quartz O.G.	0.8
Biotite	tr	Feld. O.G.	
Muscovite	tr	Dolomite	tr
Heavy Min.	2.0	Pyrite	
Glauconite	0.8	Iron Oxide	0.8
Organics	tr	TiO_2	0.8
		Organic	

Photomicrograph Captions

Plate 1A: This soil sample consists of poorly sorted, silty sand. The white grains are nearly all quartz, but with small amounts of feldspar (mostly K-feldspar). Black grains in the upper-left and upper-right corners of the photo are magnetite/ilmenite. The well rounded, green grain in the lower-left quadrant is glauconite. Some quartz is slightly dissolved (pitted grains), as evidenced by traces of blue epoxy within the grains.

Plate 1B: A high-magnification view of the sample reveals dark-colored coatings on some grains and dark specks between grains. These dark brown to black materials are mostly iron oxide (hematite) and titanium oxide. No lead compounds are identified; however, traces of lead compounds may be associated with these dark crusts and specks. A quartz overgrowth (QO) is observed on top of a hematite grain coating. Tiny white grains between the larger grains are mainly quartz silt, along with small amounts of muscovite/sericite flakes (M).

CORELAB

THIN SECTION PETROGRAPHY

Plate 2A

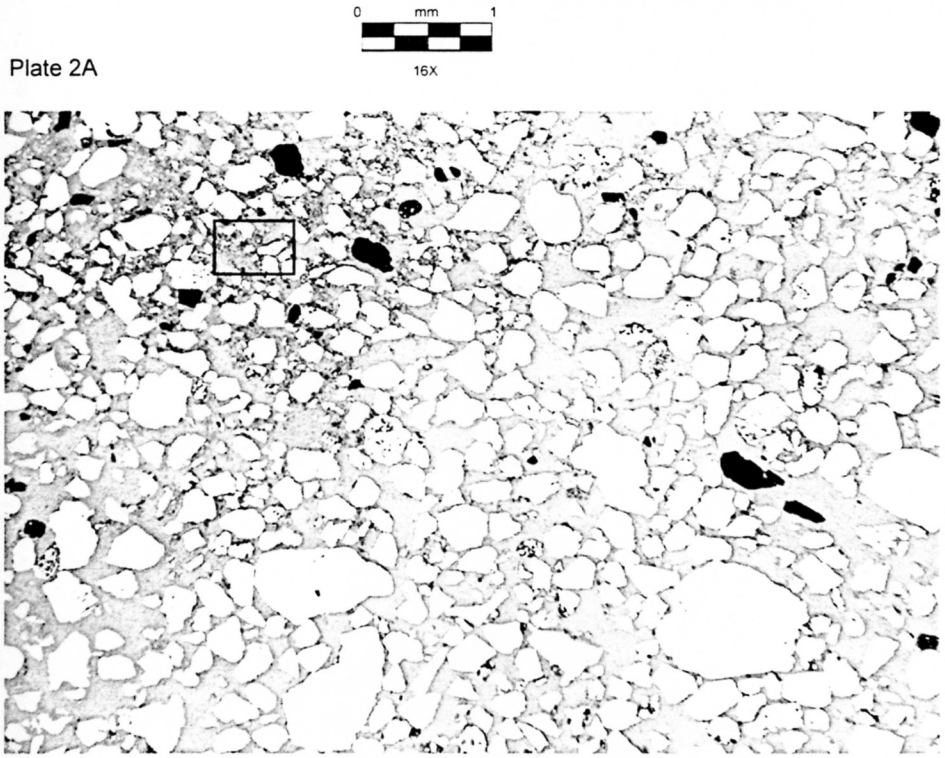
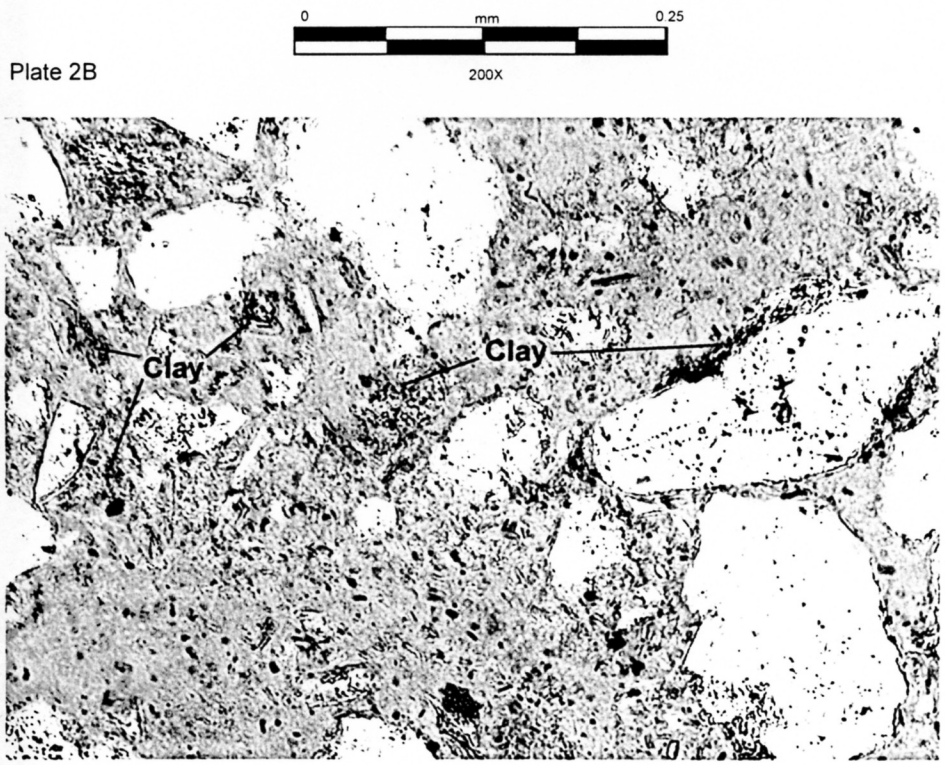


Plate 2B



GeoSyntec Consultants
Soil Samples
NL Industries Project
Sample: SV28071698
Depth: 12 - 16 feet

Soil Type & Texture

Classification (Folk)	Silty sand
Grain Size (mm)	Range = <0.01 - 2.18
(estimated)	Avg. = 0.38 (med. sand)
Grain Sorting	Poor
Grain Roundness	Rounded to angular
Compaction	Disaggregated
Structures	None evident

Composition (%)

Detrital Grains		**Detrital Matrix**	
Mono. Qtz.	80.8	Clay	2.8
Poly. Qtz.	10.8	**Authigenic Clay**	
K-feldspar	0.8	Kaolinite	tr
Plagioclase	tr	Chlorite	tr
Igneous R.F.	tr	Sericite	tr
Sedim. R.F.	tr	Undiff. I/S	0.4
Meta. R.F.	0.8	**Cements (non-clay)**	
Chert	1.2	Quartz O.G.	0.4
Biotite		Feld. O.G.	
Muscovite	tr	Dolomite	tr
Heavy Min.	0.4	Pyrite	
Glauconite	tr	Iron Oxide	0.4
Organics		TiO_2	1.2
		Organic	

Photomicrograph Captions

Plate 2A: This sample is very similar to the previous sample (Plate 1). A lower magnification is provided here, compared to Plate 1A, so that the silty texture of the sand is better observed (upper-left quadrant). Scattered dark grains are heavy minerals. The blackest grains are magnetite/ilmenite.

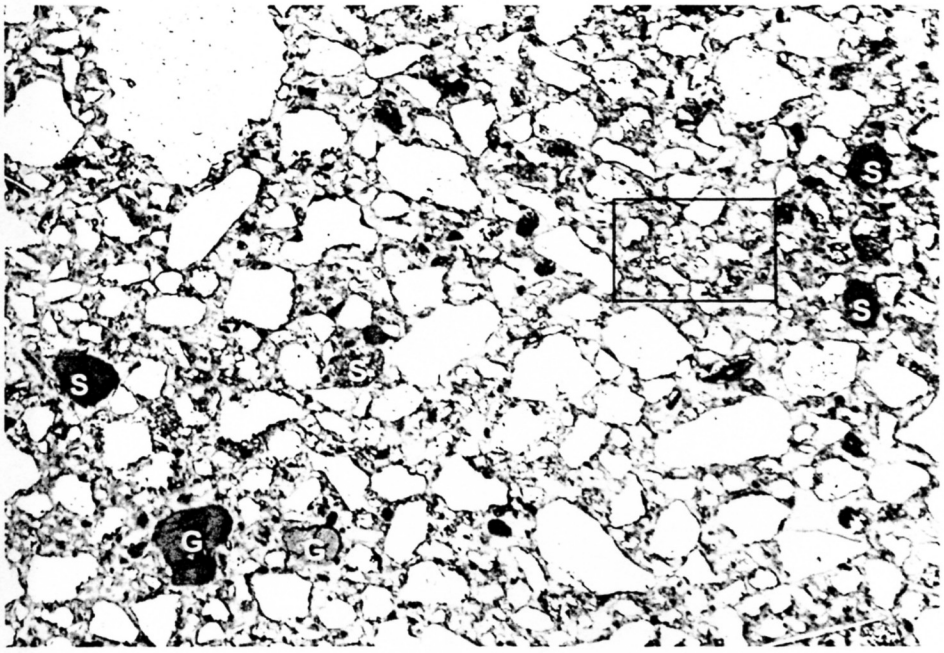
Plate 2B: The area within the black rectangle in Plate 2A is presented in this photomicrograph. The main difference between this sample and SV26072098 is that this sample contains greater (although minor) amounts of clay matrix (yellowish green). This intergranular to grain-coating clay contains many tiny specks of titanium and iron oxides (black). Some of this micron-sized material may include lead compounds, but this cannot be established with thin section analysis. XRD analysis reveals that the clays in this sample are kaolinite and illite/mica.

THIN SECTION PETROGRAPHY

0 mm 1

31X

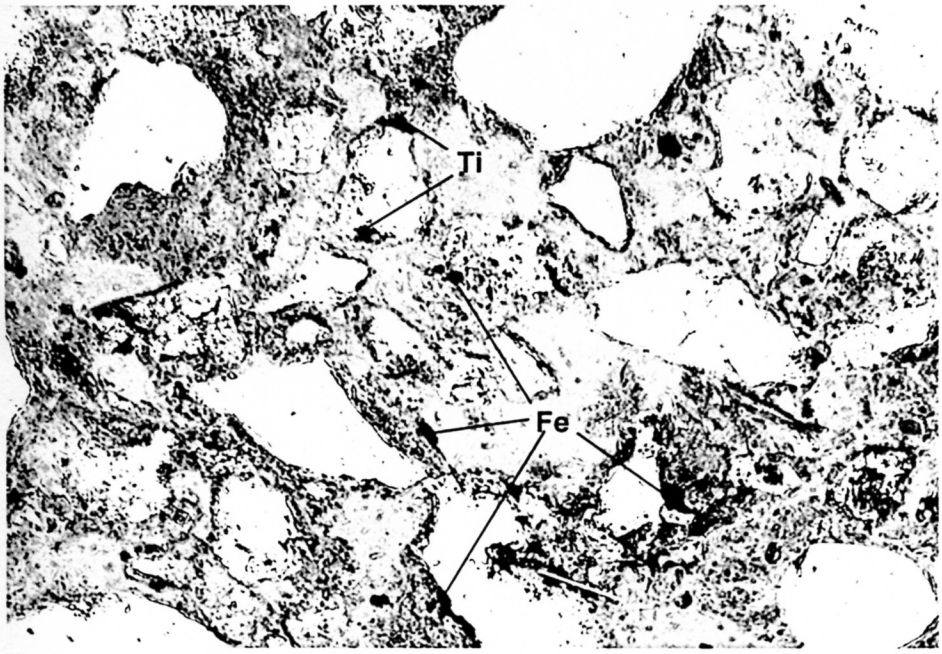
Plate 3A



0 mm 0.25

200X

Plate 3B



GeoSyntec Consultants
Soil Samples
NL Industries Project
Sample: SV29071598
Depth: 10 - 16 feet

Soil Type & Texture	
Classification (Folk)	Muddy sand
Grain Size (mm)	Range = <0.01 - 2.02
(estimated)	Avg. = 0.28 (med. sand)
Grain Sorting	Poor
Grain Roundness	Rounded to angular
Compaction	Disaggregated
Structures	None evident

Composition (%)			
Detrital Grains		**Detrital Matrix**	
Mono. Qtz.	61.6	Clay	10.8
Poly. Qtz.	7.2	**Authigenic Clay**	
K-feldspar	2.4	Kaolinite	
Plagioclase	1.6	Chlorite	tr
Igneous R.F.	0.8	Sericite	tr
Sedim. R.F.	4.0	Undiff. I/S	tr
Meta. R.F.	2.4	**Cements (non-clay)**	
Chert	0.4	Quartz O.G.	0.8
Biotite	tr	Feld. O.G.	
Muscovite	1.6	Dolomite	
Heavy Min.	1.6	Pyrite	
Glauconite	0.4	Iron Oxide	2.4
Organics		TiO_2	1.6
		Organic	0.4

Photomicrograph Captions

Plate 3A: This is a poorly sorted, muddy sand sample. It is classified as muddy because of the common amounts of silt and clay occurring between the predominant sand grains. The white grains are mostly quartz, with minor amounts of K-feldspar and plagioclase. Various sedimentary argillaceous rock fragments (S) appear dark. Glauconite (G) grains are also noted. The one on the left appears orange due to oxidation.

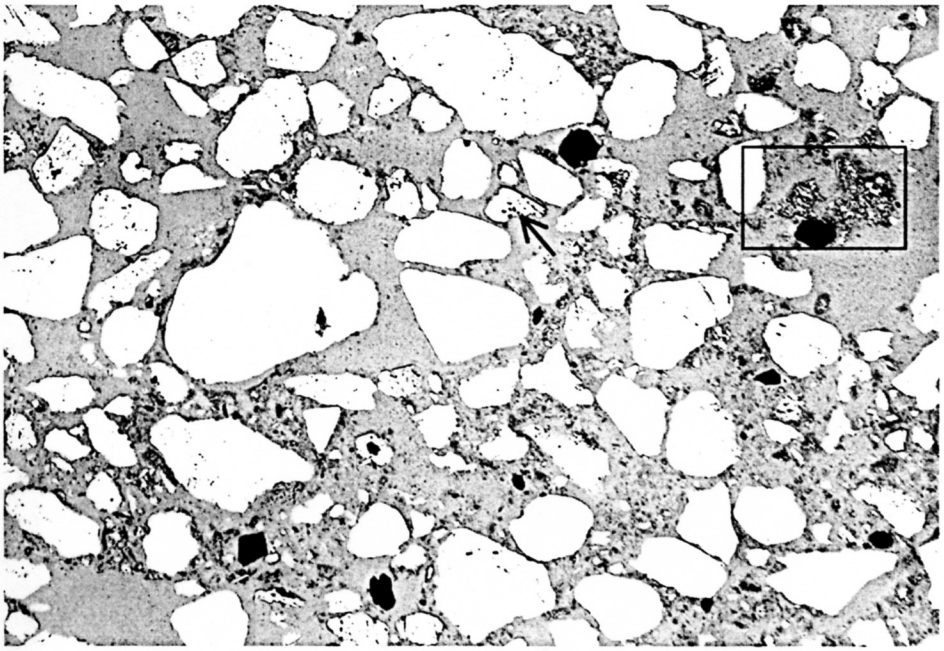
Plate 3B: The area within the black rectangle in Plate 3A is shown. This sample contains common amounts of clay matrix (greenish brown). This clay coats grains and fills pores. It consists of 78% kaolinite and 22% illite/mica, according to XRD analysis. Within the clay are dark-colored coatings and crystalline specks that are predominantly iron (Fe) and titanium (Ti) oxides. Micron-sized particles of lead compounds may possibly also be present within the clays and oxide coatings.

THIN SECTION PETROGRAPHY

0 mm 1

31X

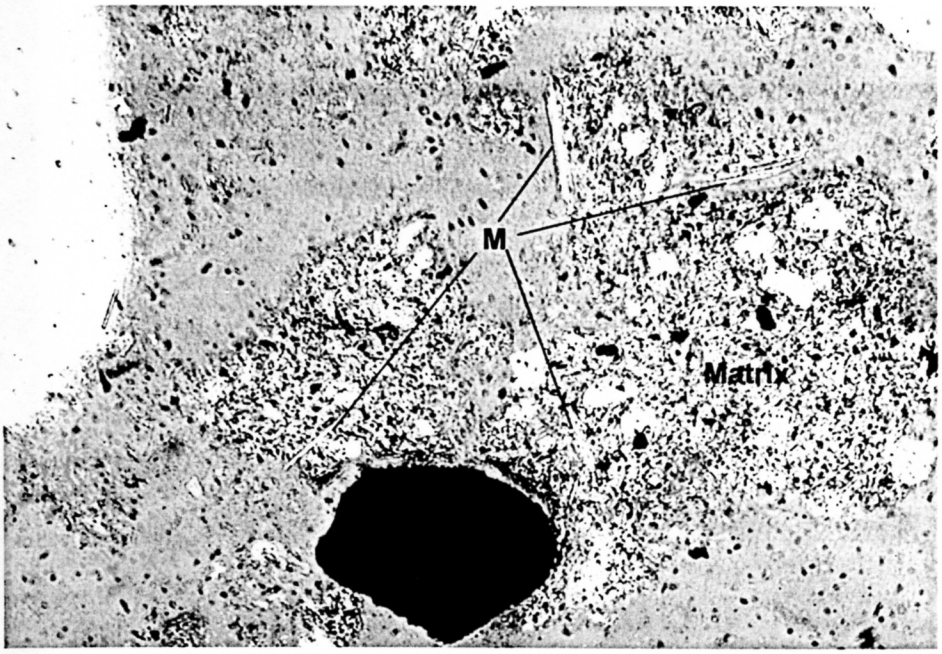
Plate 4A



0 mm 0.25

200X

Plate 4B



GeoSyntec Consultants
Soil Samples
NL Industries Project
Sample: SV40
Depth: N.A.

Soil Type & Texture

Classification (Folk)	Silty sand
Grain Size (mm)	Range = <0.01 - 2.05
(estimated)	Avg. = 0.36 (med. sand)
Grain Sorting	Poor
Grain Roundness	Rounded to angular
Compaction	Disaggregated
Structures	None evident

Composition (%)

Detrital Grains		**Detrital Matrix**	
Mono. Qtz.	76.0	Clay	2.4
Poly. Qtz.	17.2	**Authigenic Clay**	
K-feldspar	1.2	Kaolinite	tr
Plagioclase	tr	Chlorite	tr
Igneous R.F.	tr	Sericite	tr
Sedim. R.F.	0.4	Undiff. I/S	0.4
Meta. R.F.	0.4	**Cements (non-clay)**	
Chert	0.4	Quartz O.G.	tr
Biotite	tr	Feld. O.G.	
Muscovite	tr	Dolomite	
Heavy Min.	0.4	Pyrite	
Glauconite	tr	Iron Oxide	tr
Organics		TiO_2	1.2
		Organic	

Photomicrograph Captions

Plate 4A: Patches of silty clay matrix (light brown) are irregularly distributed in the thin section. This view shows an area where the matrix is relatively common. A slightly dissolved (pitted) feldspar grain is noted by the arrow. Black sand grains are ilmenite/magnetite.

Plate 4B: The portion of Plate 4A within the black rectangle is displayed. The black grain is probably magnetite that has an oxidized rim. The oxidation has stained the adjacent clay matrix brown. Most of the view features a patch of matrix consisting of detrital silt and clay. A few muscovite (M) flakes are part of the silt fraction. The numerous black specks in the matrix are titanium oxide, with traces of iron oxide and possibly other materials. If any lead compounds are present, they would be most likely to occur as very tiny crystals within this matrix. XRD analysis indicates the clay fraction of the matrix is kaolinite and illite/mica.

APPENDIX C

Toxscan, Inc. Laboratory Report (October 1998)

RECEIVED OCT 1 3 1998

ToxScan, Inc. 42 Hangar Way • Watsonville, CA 95076-2404 • (408) 724-4522 • FAX (408) 724-3188

October 08, 1998 ToxScan Number: T-16324

GeoSyntec Consultants
10015 Old Columbia Road, Suite A-200
Columbia, MD 21046

Attn: Jeffrey Moore

Project Name:	NL
Project Number:	ME0015-13
Date Sampled:	July 15, 1998 - September 23, 1998
Date Received:	August 14, 1998 - September 23, 1998
Matrix:	Soil Soil Extract

Please find the enclosed test results for the parameters requested for analyses. The samples were analyzed within holding time using the following methods:

Carbonate Cadmium by ICP/MS by EPA Method 200.8
Carbonate Lead by ICP/MS by EPA Method 200.8
Carbonate Lead by ICP/MS by EPA Method 200.8
Cation-Exchange Capacity by EPA Method 9081, conducted by Soil Control Lab
Extractable Cadmium by ICP/MS by EPA Method 200.8
Extractable Lead by ICP/MS by EPA Method 200.8
Extractable Lead by ICP/MS by EPA Method 200.8
Iron/Manganese Oxide/Hydroxide Cadmium by ICP/MS by EPA Method 200.8
Iron/Manganese Oxide/Hydroxide Lead by ICP/MS by EPA Method 200.8
Iron/Manganese Oxide/Hydroxide Lead by ICP/MS by EPA Method 200.8
Organic Cadmium by ICP/MS by EPA Method 200.8
Organic Lead by ICP/MS by EPA Method 200.8
Organic Lead by ICP/MS by EPA Method 200.8
[1] Particle Size Distribution by Plumb
Percent Solids by EPA Method 160.3
pH by EPA Method 9045B
Residual Cadmium by ICP/MS by EPA Method 200.8
Residual Lead by ICP/MS by EPA Method 200.8
Residual Lead by ICP/MS by EPA Method 200.8
Total Metals by ICP/MS (Cd,Pb) by EPA Method 6020

This cover letter is an integral part of the report.

[1] Russell H. Plumb, Jr.; Procedures for Handling and Chemical Analysis of Sediment and Water Samples, Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station; 1981.

ToxScan, Inc. 42 Hangar Way • Watsonville, CA 95076-2404 • (408) 724-4522 • FAX (408) 724-3188

October 08, 1998

ToxScan Number: T-16324

GeoSyntec Consultants
10015 Old Columbia Road, Suite A-200
Columbia, MD 21046

Attn: Jeffrey Moore

The samples were received intact and were handled with the proper chain-of-custody procedures. Appropriate QA/QC guidelines were employed during the analyses on a minimum of a 5% basis. QC results were within limits and are reported with or following the data for each analysis.

If you have any questions or require any additional information, please feel free to call.

Sincerely,

Philip D. Carpenter, Ph.D.
President

Enclosures

This cover letter is an integral part of the report.

[1] Russell H. Plumb, Jr.; Procedures for Handling and Chemical Analysis of Sediment and Water Samples, Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station; 1981.

Client: GeoSyntec Consultants
Method: EPA Method(s) 200.8
Date Completed: 9/29/98
Matrix: Soil Extract
Units: mg/Kg

ToxScan Number: T-16324

Carbonate Metals

Client Sample ID	ToxScan Lab ID	Analyte	Sample Value	Reporting Limit
SV2910-12071598	16324-09	Cadmium	ND	0.1
		Lead	ND	0.1
SV2812-16071698	16324-10	Cadmium	ND	0.1
		Lead	0.17	0.1
SV071698-Dup	16324-11	Cadmium	ND	0.1
		Lead	0.14	0.1
SV26072098	16324-12	Cadmium	ND	0.1
		Lead	ND	0.1

ANALYTICAL CHEMISTS
and
BACTERIOLOGISTS
Approved by State of California

SOIL CONTROL LAB

42 HANGAR WAY
WATSONVILLE
CALIFORNIA
95076
USA

A Division of Control Laboratories Inc.

Tel: 831 724-5422
FAX: 831 724-3188

In any reference, please quote Certified Analysis Number appearing hereon.

130152-4-3344

ToxScan Inc.
42 Hangar Way
Watsonville, CA 95076

05 OCT 98

CERTIFIED ANALYTICAL REPORT

MATERIAL: **Soil samples received 27 August 1998**
IDENTIFICATION: **T-16324, Quanterra**
ID NUMBERS: **1/4-4/4-130152**

Sample ID:	Cation Exchange Capacity (C.E.C.)
SV2910-12071598	3.57 meq/100 g dw
Dup	1.70 meq/100 g dw
SV2812-16071698	1.13 meq/100 g dw
Dup	0.89 meq/100 g dw
SV071698-Dup	0.91 meq/100 g dw
Dup	0.91 meq/100 g dw
SV26072098	2.72 meq/100 g dw
Dup	1.83 meq/100 g dw

The undersigned certifies that the above is a true and accurate report of the findings of this Laboratory.

Analyst

Client: GeoSyntec Consultants
Method: EPA Method(s) 200.8
Date Completed: 9/29/98
Matrix: Soil Extract
Units: mg/Kg

ToxScan Number: T-16324

Extractable Metals

Client Sample ID	ToxScan Lab ID	Analyte	Sample Value	Reporting Limit
SV2910-12071598	16324-09	Cadmium	ND	0.1
		Lead	ND	0.1
SV2812-16071698	16324-10	Cadmium	ND	0.1
		Lead	ND	0.1
SV071698-Dup	16324-11	Cadmium	ND	0.1
		Lead	ND	0.1
SV26072098	16324-12	Cadmium	ND	0.1
		Lead	ND	0.1

Client: GeoSyntec Consultants
Method: EPA Method(s) 200.8
Date Completed: 9/29/98
Matrix: Soil Extract
Units: mg/Kg

ToxScan Number: T-16324

Iron/Manganese

Client Sample ID	ToxScan Lab ID	Analyte	Sample Value	Reporting Limit
SV2910-12071598	16324-09	Cadmium	ND	0.1
		Iron	120	0.1
		Lead	0.36	0.1
		Manganese	33	0.1
SV2812-16071698	16324-10	Cadmium	ND	0.1
		Iron	26	0.1
		Lead	ND	0.1
		Manganese	ND	0.1
SV071698-Dup	16324-11	Cadmium	ND	0.1
		Iron	28	0.1
		Lead	ND	0.1
		Manganese	ND	0.1
SV26072098	16324-12	Cadmium	ND	0.1
		Iron	34	0.1
		Lead	0.14	0.1
		Manganese	ND	0.1

Client: GeoSyntec Consultants
Method: EPA Method(s) 200.8
Date Completed: 9/29/98
Matrix: Soil Extract
Units: mg/Kg

ToxScan Number: T-16324

Bound Organic Metals

Client Sample ID	ToxScan Lab ID	Analyte	Sample Value	Reporting Limit
SV2910-12071598	16324-09	Cadmium	ND	0.1
		Lead	ND	0.1
SV2812-16071698	16324-10	Cadmium	ND	0.1
		Lead	ND	0.1
SV071698-Dup	16324-11	Cadmium	ND	0.1
		Lead	ND	0.1
SV26072098	16324-12	Cadmium	ND	0.1
		Lead	ND	0.1

Client:	GeoSyntec Consultants	ToxScan Number: 16324
Method:	Plumb	
Date Analyzed:	August 3 - September 8, 1998	
Matrix:	Sediment	

Client Sample ID:	SV2910-12071598
Client Site ID:	
ToxScan Lab ID:	T-16324-05A

SIZE INTERVAL Phi	mm	INTERVAL WT (gm)	INTERVAL (%)	CUMULATIVE (%)
<-5	>32	0.00	0.0	0.0
-4	32-16	0.00	0.0	0.0
-3	16- 8	0.00	0.0	0.0
-2	8- 4	0.13	0.3	0.3
-1	4- 2	0.08	0.2	0.5
0	2- 1	0.16	0.4	0.9
1	1-0.5	2.26	5.3	6.2
2	0.5-0.25	12.57	29.4	35.6
3	0.25-0.125	16.85	39.5	75.1
4	0.125-0.062	8.01	18.8	93.9
5	0.062-0.031	1.23	2.9	96.7
6	0.031-0.016	0.41	1.0	97.7
7	0.016-0.008	0.29	0.7	98.4
8	0.008-0.004	0.16	0.4	98.7
9	0.004-0.002	0.08	0.2	98.9
>9	< 0.002	0.45	1.1	100

total wt	coarse wt	fine wt
42.7	40.1	2.6

% sand	% silt	% clay
93.9	4.9	1.3

GeoSyntec Consultants
Plumb
August 3 - September 8, 1998
Sediment

ToxScan Number: 16324

SV2812-16071698

T-16324-06A

INTERVAL WT (gm)	INTERVAL (%)	CUMULATIVE (%)
0.00	0.0	0.0
0.00	0.0	0.0
0.00	0.0	0.0
1.33	3.2	3.2
0.85	2.1	5.3
1.43	3.5	8.7
6.81	16.5	25.3
19.83	48.1	73.3
8.76	21.2	94.5
0.86	2.1	96.6
0.25	0.6	97.2
0.19	0.5	97.7
0.21	0.5	98.2
0.12	0.3	98.5
0.09	0.2	98.7
0.54	1.3	100

total wt	coarse wt	fine wt
41.3	39.9	1.4

% sand	% silt	% clay
96.6	1.8	1.5

Client:	GeoSyntec Consultants	ToxScan Number: 16324
Method:	Plumb	
Date Analyzed:	August 3 - September 8, 1998	
Matrix:	Sediment	

Client Sample ID:	SV071698-Dup
Client Site ID:	
ToxScan Lab ID:	T-16324-07A

SIZE INTERVAL Phi	mm	INTERVAL WT (gm)	INTERVAL (%)	CUMULATIVE (%)
<-5	>32	0.00	0.0	0.0
-4	32-16	0.00	0.0	0.0
-3	16- 8	0.00	0.0	0.0
-2	8- 4	3.01	7.0	7.0
-1	4- 2	1.30	3.0	10.0
0	2- 1	2.20	5.1	15.2
1	1-0.5	7.09	16.5	31.7
2	0.5-0.25	19.35	45.1	76.8
3	0.25-0.125	7.91	18.4	95.2
4	0.125-0.062	0.76	1.8	97.0
5	0.062-0.031	0.20	0.5	97.5
6	0.031-0.016	0.21	0.5	98.0
7	0.016-0.008	0.16	0.4	98.3
8	0.008-0.004	0.13	0.3	98.6
9	0.004-0.002	0.06	0.1	98.8
>9	< 0.002	0.53	1.2	100

total wt	coarse wt	fine wt
42.9	41.6	1.3

% sand	% silt	% clay
97.0	1.6	1.4

Client:	GeoSyntec Consultants	ToxScan Number: 16324
Method:	Plumb	
Date Analyzed:	August 3 - September 8, 1998	
Matrix:	Sediment	
Client Sample ID:	SV26072098	
Client Site ID:		
ToxScan Lab ID:	T-16324-08A	

SIZE INTERVAL Phi mm	INTERVAL WT (gm)	INTERVAL (%)	CUMULATIVE (%)
<-5 >32	0.00	0.0	0.0
-4 32-16	0.00	0.0	0.0
-3 16- 8	0.00	0.0	0.0
-2 8- 4	8.39	18.9	18.9
-1 4- 2	0.22	0.5	19.4
0 2- 1	0.31	0.7	20.1
1 1-0.5	2.23	5.0	25.1
2 0.5-0.25	10.95	24.6	49.7
3 0.25-0.125	13.97	31.4	81.1
4 0.125-0.062	5.39	12.1	93.2
5 0.062-0.031	0.76	1.7	94.9
6 0.031-0.016	0.46	1.0	95.9
7 0.016-0.008	0.33	0.8	96.7
8 0.008-0.004	0.31	0.7	97.4
9 0.004-0.002	0.14	0.3	97.7
>9 < 0.002	1.02	2.3	100

total wt	coarse wt	fine wt
44.5	41.5	3.0

% sand	% silt	% clay
93.2	4.2	2.6

Client: GeoSyntec Consultants
Method: EPA Method(s) 160.3
Date Completed: 8/26/98
Matrix: Soil
Units: Percent

ToxScan Number: T-16324

Client Sample ID	ToxScan Lab ID	Analyte	Wet Wt. Sample Value	Wet Reporting Limit
SV2910 - 12071598	16324-05	Percent Solids	83	0.10
SV2812 - 16071698	16324-06	Percent Solids	82	0.10
SV071698 - Dup	16324-07	Percent Solids	84	0.10
SV26072098	16324-08	Percent Solids	80	0.10

Client: GeoSyntec Consultants
Method: EPA Method(s) 9045B
Date Completed: 9/3/98
Matrix: Soil
Units: units

ToxScan Number: T-16324

Client Sample ID	ToxScan Lab ID	Analyte	Sample Value	Reporting Limit
SV2910 - 12071598	16324-05	pH	7.3	0.10
SV2812 - 16071698	16324-06	pH	6.6	0.10
SV071698 - Dup	16324-07	pH	6.0	0.10
SV26072098	16324-08	pH	6.2	0.10

Client: GeoSyntec Consultants
Method: EPA Method(s) 200.8
Date Completed: 9/29/98
Matrix: Soil Extract
Units: mg/Kg

ToxScan Number: T-16324

Residual Metals

Client Sample ID	ToxScan Lab ID	Analyte	Sample Value	Reporting Limit
SV2910-12071598	16324-09	Cadmium	ND	0.1
		Lead	2.2	0.1
SV2812-16071698	16324-10	Cadmium	ND	0.1
		Lead	0.96	0.1
SV071698-Dup	16324-11	Cadmium	ND	0.1
		Lead	0.87	0.1
SV26072098	16324-12	Cadmium	ND	0.1
		Lead	1.6	0.1

Client: GeoSyntec Consultants
Method: EPA Method(s) 6020
Date Completed: 9/10/98
Matrix: Soil
Units: mg/Kg

ToxScan Number: T-16324

Total Metals

Client Sample ID	ToxScan Lab ID	Analyte	Wet Wt. Sample Value	Wet Reporting Limit
SV2910 - 12071598	16324-05	Cadmium	ND	0.10
		Lead	2.8	0.10
SV2812 - 16071698	16324-06	Cadmium	ND	0.10
		Lead	1.9	0.10
SV071698 - Dup	16324-07	Cadmium	ND	0.10
		Lead	2.3	0.10
SV26072098	16324-08	Cadmium	ND	0.10
		Lead	4.1	0.10

EXPLANATION OF ACRONYMS FOR PROJECT # T-16324

The following is a glossary for acronyms that may be used in this report.

Abbreviation	Definition
LCS	Laboratory Control Sample
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NA	Not Applicable
ND	None Detected
REP	Replicate
RPD	Relative Percent Difference
SRM	Standard Reference Material
TOC	Total Organic Carbon

QC FOR PROJECT # T-16324

LABORATORY METHOD BLANK SUMMARY

Applicable Matrix: Sediment

Total Metals

Analyte	Amount	Reporting Limit mg/L	EPA Method Number
Cadmium	ND	0.10	6020
Iron	ND	1.0	7380
Lead	ND	0.10	6020
Manganese	ND	0.10	6020

QC FOR PROJECT # T-16324

LABORATORY PRECISION SUMMARY:
Matrix: Soil

Analyte	REP 1	REP 2	Units	RPD
pH				
16324-08	6.20	6.19	units	0

QC FOR PROJECT # T-16324

Concentrations of the following are in mg/Kg

SRM SUMMARY:

Matrix: Sediment

Total Metals

Analyte	Amount Found	Dilution	Corrected Value	SRM	Certified Value	% Recovery
Cadmium	0.0136	20	0.272	MESS-2	0.240	114
Lead	0.955	20	19.1	MESS-2	21.9	87

QC FOR PROJECT # T-16324

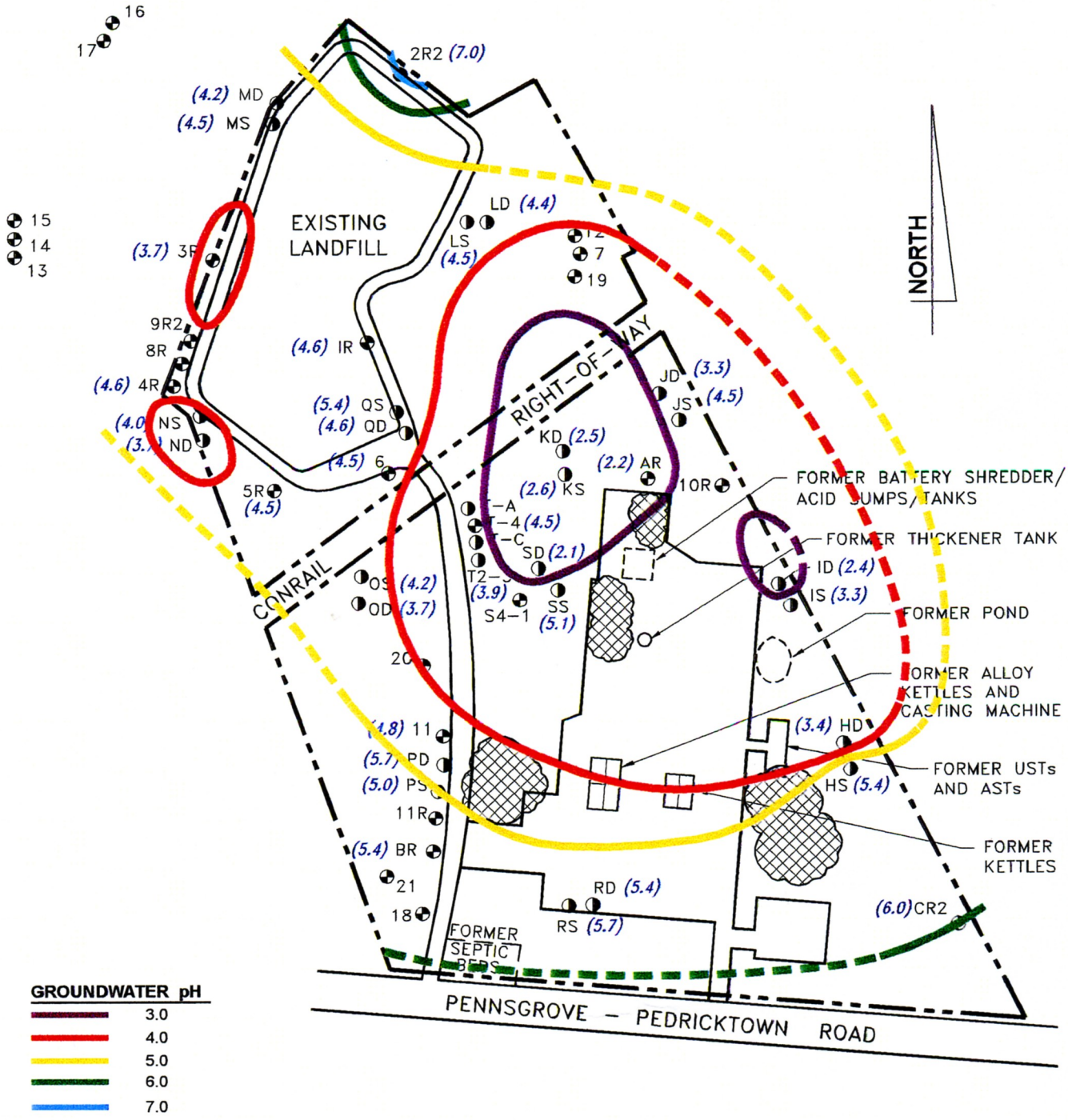
Concentrations of the following are in ug/L

SRM SUMMARY:
Matrix: Water
Total Metals

Analyte	Amount Found	Dilution	Corrected Value	SRM	Certified Value	% Recovery
Cadmium	24.0	5	120	ERA 9977	120	100
Iron	676	1	676	ERA 9977	667	101
Lead	128	5	641	ERA 9977	660	97
Manganese	18.6	5	93.0	ERA 9977	100	93

ERA 9977 = Environmental Resource Associates, WasteWatR Lot No. 9977

APPENDIX D
Current and Historical Groundwater pH Isopleths



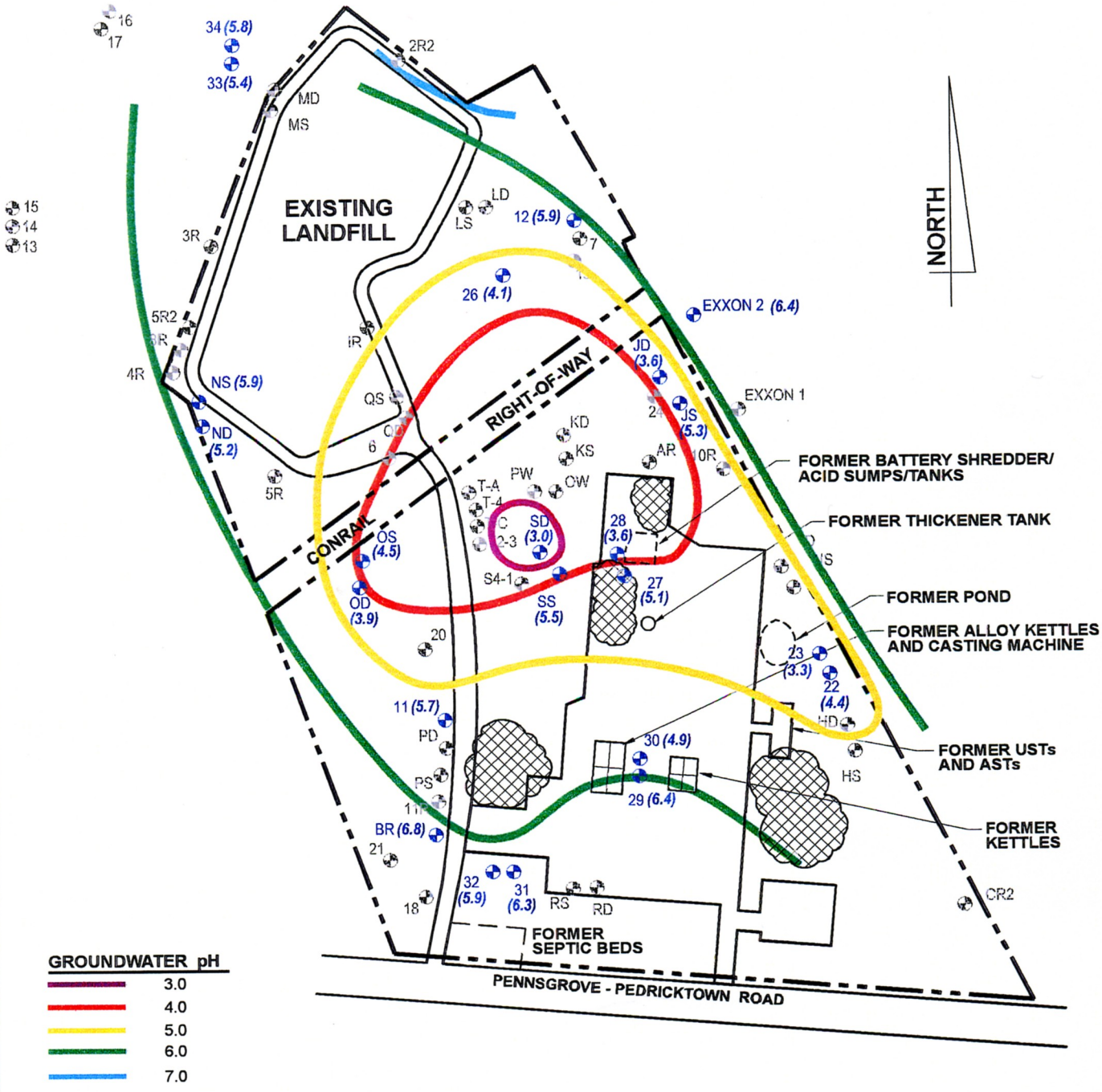
NOTE: GROUNDWATER pH CONTOURS SHOWN ARE A REPRESENTATIVE COMPOSITE OF DATA FROM SHALLOW AND DEEP WELLS IN THE UNCONFINED AQUIFER.

pH of Groundwater - 1983

NL Industries Site
Pedricktown, New Jersey

GeoSyntec Consultants
COLUMBIA, MARYLAND

FIGURE NO.	7-5
PROJECT NO.	ME0015-15
DOCUMENT NO.	-
FILE NO.	phs2-pH83



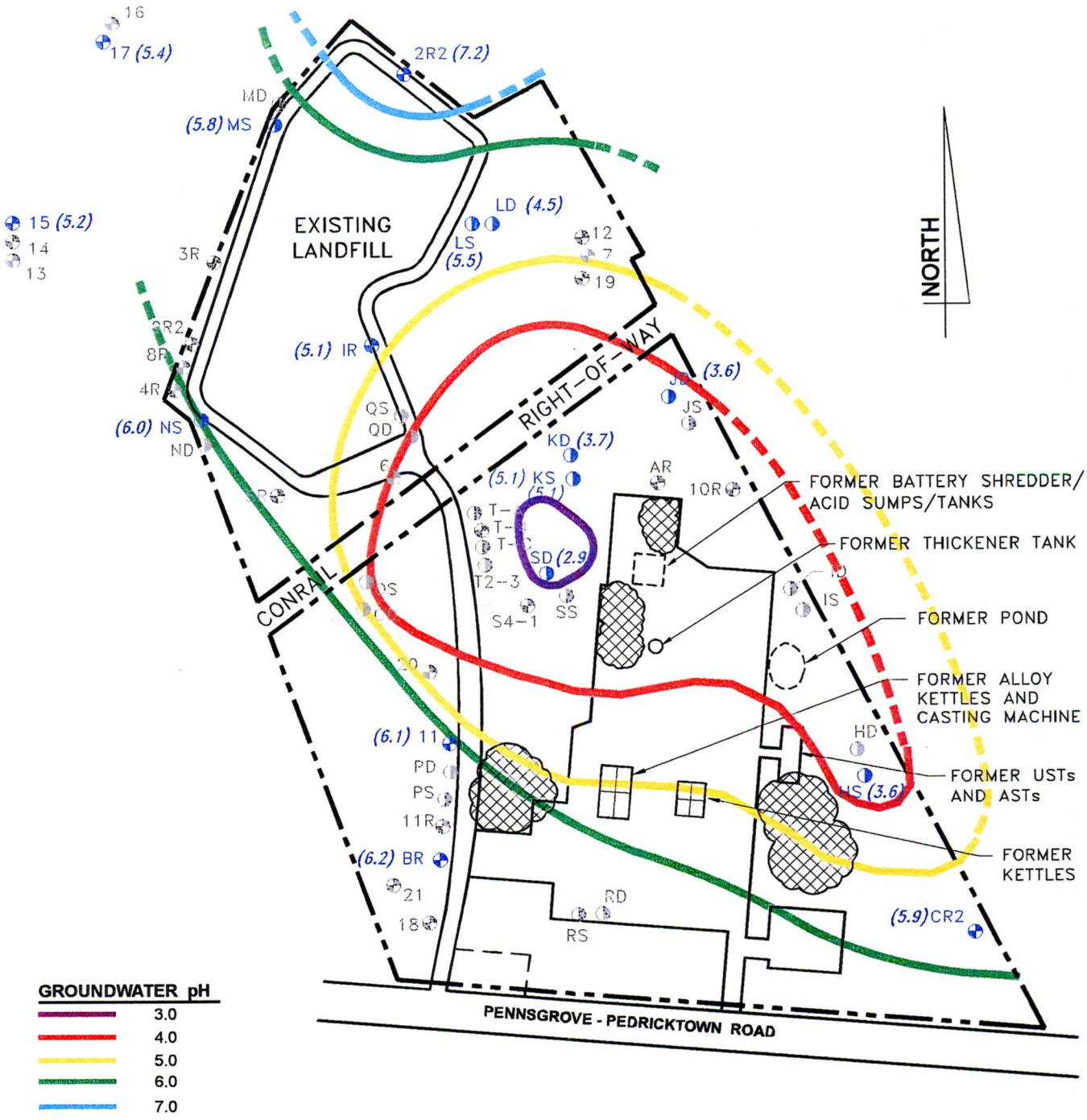
NOTE: GROUNDWATER pH CONTOURS SHOWN ARE A REPRESENTATIVE COMPOSITE OF DATA FROM SHALLOW AND DEEP WELLS IN THE UNCONFINED AQUIFER.

pH of Groundwater - 1998

NL Industries Site
Pedricktown, New Jersey

GeoSyntec Consultants
COLUMBIA, MARYLAND

FIGURE NO.	7-3
PROJECT NO.	ME0015-15
DOCUMENT NO.	-
FILE NO.	phs2-pH98



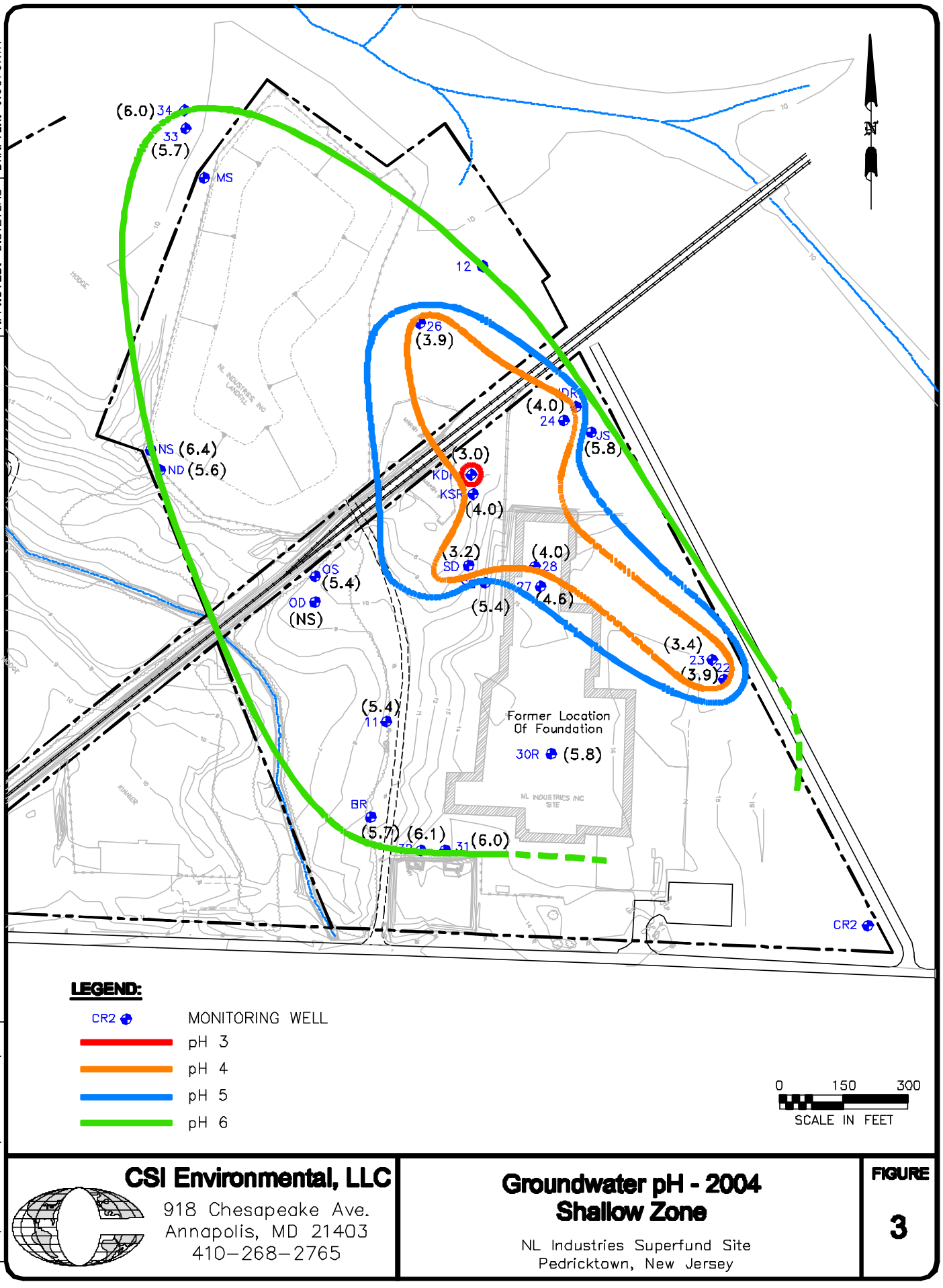
NOTE: GROUNDWATER pH CONTOURS SHOWN ARE A REPRESENTATIVE COMPOSITE OF DATA FROM SHALLOW AND DEEP WELLS IN THE UNCONFINED AQUIFER.

pH of Groundwater - 1997

NL Industries Site
Pedricktown, New Jersey

GeoSyntec Consultants
COLUMBIA, MARYLAND

FIGURE NO.	7-4
PROJECT NO.	ME0015-15
DOCUMENT NO.	-
FILE NO.	phs2-pH97



APPROVED: C.STEVENS | DRAFTER: J.GOFORTH

Path\Name : C:\LIBRARY\csi\NL\PH-CONC.dwg

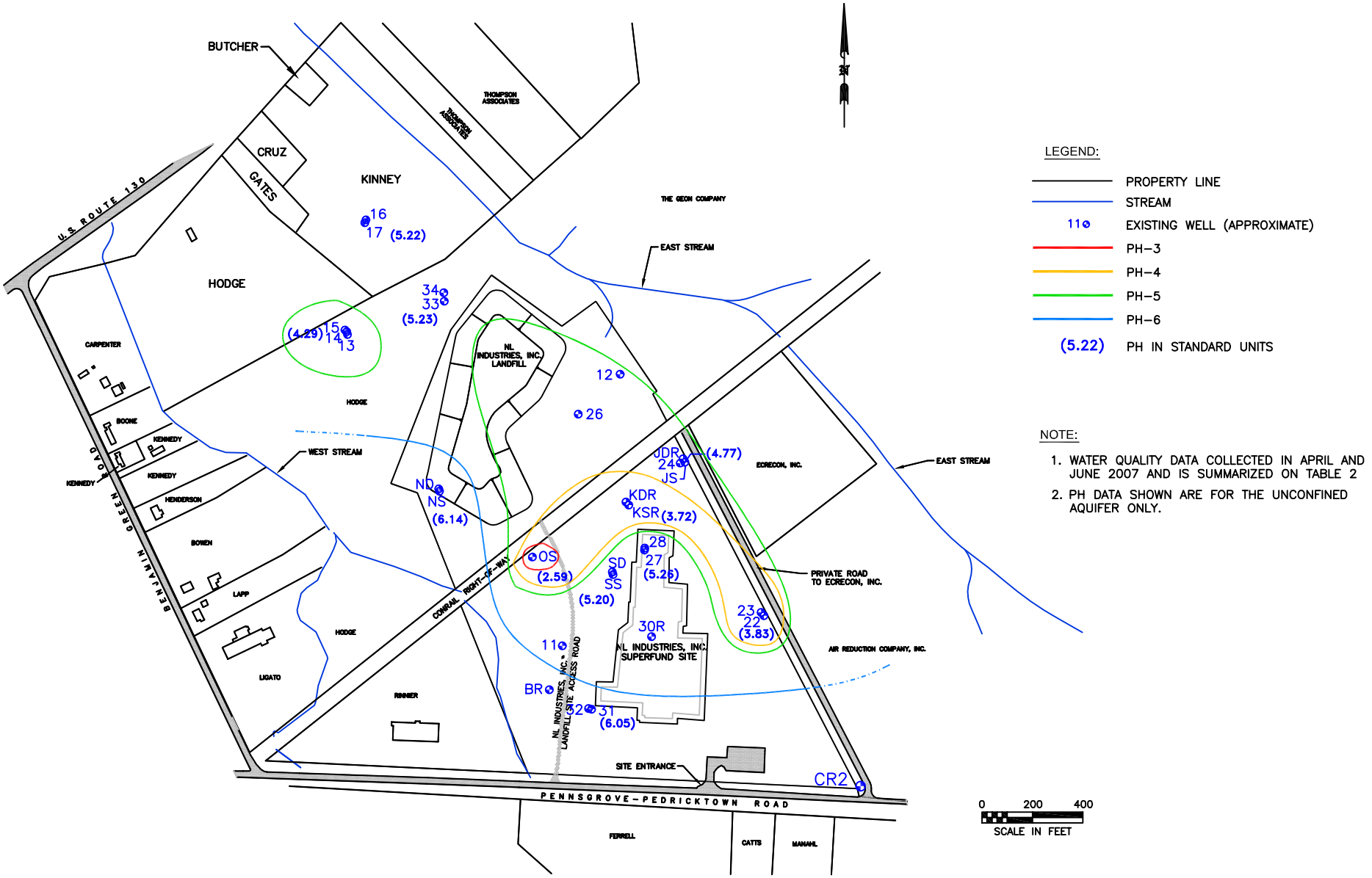
Date\Time - Wed, 14 Apr 2004 - 12:43pm

CSI Environmental, LLC
918 Chesapeake Ave.
Annapolis, MD 21403
410-268-2765

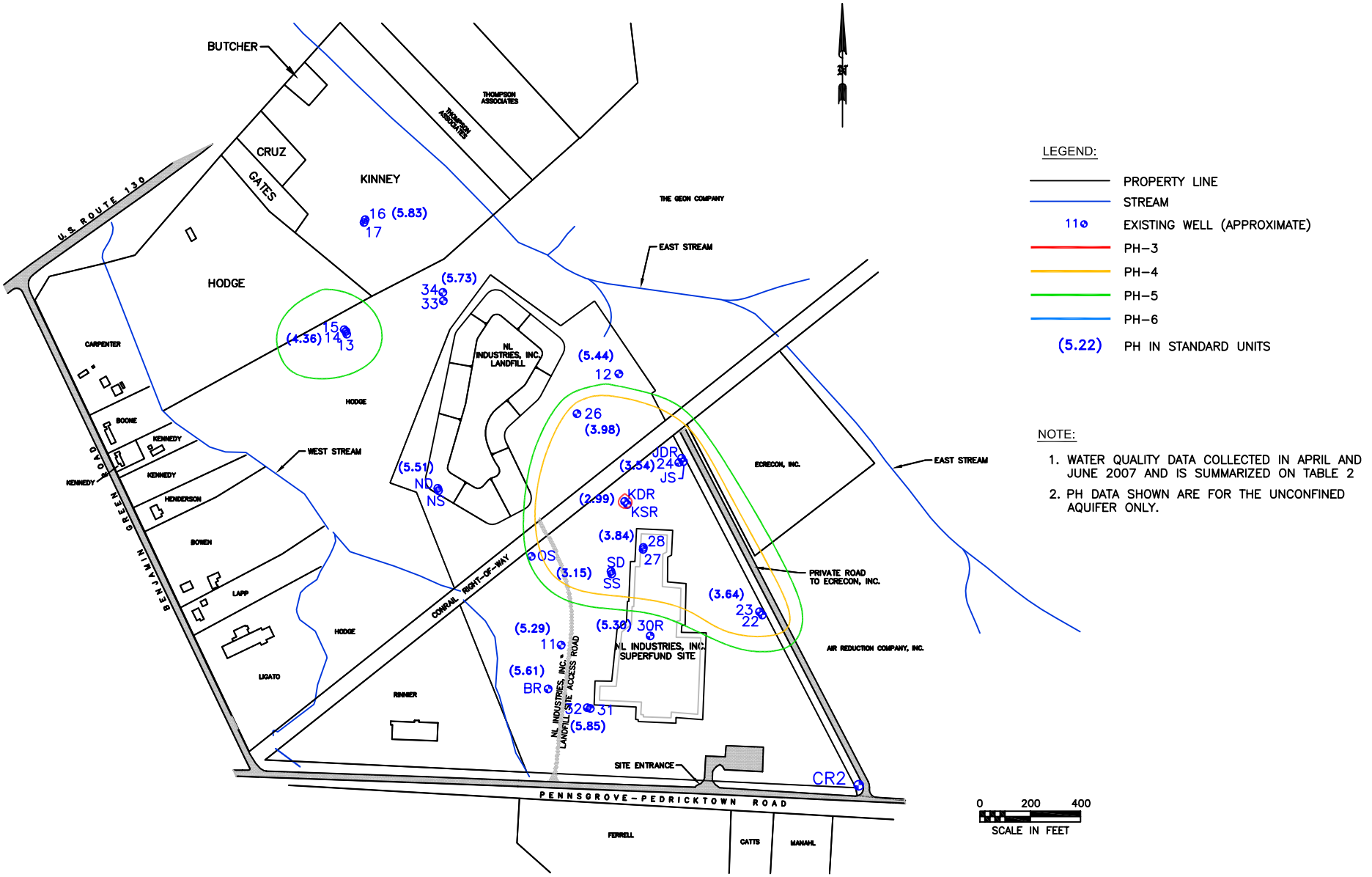
Groundwater pH - 2004 Shallow Zone

NL Industries Superfund Site
Pedricktown, New Jersey

FIGURE
3



CSI Environmental, LLC 918 Chesapeake Ave. Annapolis, MD 21403 410-268-2765		Groundwater PH - 2007 Shallow Zone NL Industries Superfund Site Pedricktown, New Jersey	FIGURE 3



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918 Chesapeake Ave.
Annapolis, MD 21403
410-268-2765

Groundwater PH - 2007 Deep Zone

NL Industries Superfund Site
Pedricktown, New Jersey

FIGURE 4

APPENDIX E
Reagent Injection Bench Scale Treatability Study

WRT SERVICES, INC.

August 25, 2007

Mr. Jeff Moore
Senior Project Manager
Construction Services International, Inc.
918 Chesapeake Ave.
Annapolis, MD 21403

Re: NL Industries

Dear Jeff:

WRT Services conducted a laboratory bench study on behalf of CSI. The objective is to determine metal stabilization techniques for use at the NL Industries site, located in Pedricktown, NJ.

Background:

WRT Services was provided preliminary guidance for the bench tests as described in Section 3.3.3 Bench Scale Treatability Study, attached.

Water samples were obtained from four monitoring wells at the site. The samples were tested for:

Lead
Cadmium
Iron
Manganese
Calcium
COD
TOC
Sulfide
Chloride
Total Alkalinity
Total Hardness

The groundwater is contaminated with lead and cadmium. These metals form insoluble complexes with several anions, including sulfide, carbonate, and phosphate. The ultimate treatment objective is to precipitate the target metals in situ and immobilize them. This would eliminate the need for a pump and treat remediation system, at least with respect to metals removal.

Theory

Soluble metals are usually present in solution as mono, divalent, or trivalent cations. Most toxic soluble metals are present as divalent cations. These cations may be reacted with divalent anions and if their solubility product (K_{sp}) is exceeded, the reaction products precipitate from solution. A compound's solubility is proportional to its solubility Product: The smaller the solubility product, the less soluble the species.

Metal hydroxides, Me(OH), are generally two orders of magnitude more soluble than metal sulfides. Metal phosphates usually exhibit similar solubility products as metal sulfides. Note that rendering a metal insoluble does not necessarily immobilize the insoluble complex.

Metals may be immobilized by:

- Direct adsorption of a metal complex onto a substrate (i.e. the native rock)
- Incorporating the metal into a crystal lattice (interculation), and subsequent incorporation within the native rock.
- Interlocking the metal into a non-homogenous material such as concrete or glass (vitrification)

Metal sulfides tend to adsorb onto a substrate. Phosphate immobilization is somewhat more complex. A host crystal, such as calcium carbonate is formed in solution with the target metal. If the charge and atomic radius of the target metal is the proper size, the target metal is incorporated into the host crystal and simultaneously rendered insoluble and inert.

Test Considerations:

The test protocol suggests evaluating metal precipitation with three compounds: Carbonate, sulfide, or phosphate. However, cadmium carbonate has significantly higher solubility than either cadmium sulfide or cadmium phosphate. In fact cadmium carbonate it is more soluble than cadmium hydroxide. Metal hydroxide salts are generally not acceptable for in situ metal stabilization, so carbonate precipitation was eliminated from consideration.

There are other test design considerations with implications for a full scale remediation system.

Acidity/alkalinity:

From a practical viewpoint, high alkalinity and pH in excess of 7.0 are required for metal carbonate precipitation, adding to cost and application complexity. Metal phosphate precipitation also requires pH elevation, but alkalinity is not a consideration.

Safety and Toxicity:

If sodium sulfide is used for sulfide precipitation, then pH must be controlled to prevent evolution of explosive hydrogen gas. Sulfide precipitation conducted with organosulfur compounds is not subject to hydrogen gas evolution nor is pH control required.

Some organosulfur compounds, notably dithiocarbamates, are highly toxic to fresh water fish, so use of these reagents is avoided.

Cost:

Sodium sulfide is the least expensive sulfide precipitation reagent, but this was eliminated from consideration due to safety concerns.

Phosphate precipitation is not as simple as it may appear. The phosphate bearing reagent must supply the phosphate in the di-basic state. When metals form mono-basic salts with phosphate, the metal is adsorbed onto the face of the crystal, where it can be re-dissolved relatively easily. Thus, this will produce good laboratory results, but is not practical in real life applications. When metals are removed by crystalline formation with di-basic phosphate, the metals homogenously precipitate within the host crystal, effectively immobilizing the metals.

Tri-sodium polyphosphate (TSPP) was selected for use, rather than phosphorous acid, even though it is somewhat more expensive than phosphoric acid, to insure that cadmium and lead were removed as dibasic

phosphate salts. Tri-sodium polyphosphate also eliminates the safety concerns of handling strong mineral acid in field application.

Solubility Products:

$CdCO_3$	1×10^{-12}
$Cd(OH)_2$	7.2×10^{-15}
$Cd_3(PO_4)_2$	2.53×10^{-33}
CdS	3.6×10^{-29}
$Pb(OH)_2$	1.0×10^{-16}
PbS	3.4×10^{-28}
$Pb(PO_4)$	

Baseline Groundwater Chemistry

		TDS ppm	pH	Cadmium ppb	Lead ppb	Iron ppm	Manganese ppm
Sample Location							
Well	SD	28,500	3.08	149	31	294	8.0
Well	OS	5,400	3.09	4	388	8	0.2
Well	SS	767	5.25	11	83	24	0.5
Well	KDR	5,740	2.83	141	ND	78	4.0

Test Procedure:

Reagent Selection:

1. Tri-sodium phosphate (TSPP) was chosen to generate calcium phosphate in the presence of lead and cadmium.
2. Calcium chloride solution was used in conjunction with TSP to supply the calcium ion required to form calcium phosphate.
3. A 5% solution of sodium hydroxide was used for pH adjustment in all experiments requiring pH increase.
4. A liquid organosulfur compound, Trimercaptotriazine (TMT-15, manufactured by Degussa), was chosen to precipitate lead and cadmium. TMT was selected as the reagent because it has essentially no aquatic toxicity as use concentration.

Test matrix:

Three sets of tests were conducted on each sample point. The objective was to simultaneously precipitate cadmium and lead.

Test A: No pH adjustment.
Determine the dose of Trimercaptotriazine required for each sample.
The dose is determined by:
- Calculating the stoiciometric demand to precipitate all the known metals (iron, manganese, cadmium, and lead).
- Add TMT-15 at 1.5 times the stoiciometric requirement to compensate for any reagent demand from unknown metals.

Mix for 30 seconds at 120 rpm using a Phipps and Bird mechanical stirrer (gang stirrer).
Allow to stand and settle for five (5) minutes.
Filter through # 40 Whatman paper and retain filtrate for metals analysis
Acidify and refrigerate retained samples

Ship to Lancaster Laboratories for cadmium and lead determination.

Test B: Qualifiers:

1. Sulfide precipitation is usually conducted at mildly alkaline pH.
   Each groundwater was acidic: Several are strongly acidic.
   Determine if pH adjustment is required to augment sulfide precipitation

2. Iron and manganese create demand for sulfide reagent.
   Iron and manganese may be inexpensively precipitated by pH adjustment in excess of 8.0, using (inexpensive) sodium hydroxide.
   If iron is removed as iron hydroxide, the sulfide reagent can be preserved to precipitate the more soluble metals, cadmium and lead, at relatively lower cost.

Adjust pH to 8.5.
Add 30 ppm, active ingredient basis, of Trimercaptotriazine
Mix for 30 seconds at 120 rpm using a Phipps and Bird mechanical stirrer (gang stirrer).
Allow to stand and settle for five (5) minutes.
Filter through # 40 Whatman paper and retain filtrate for metals analysis
Acidify and refrigerate retained samples
Ship to Lancaster Laboratories for cadmium and lead determination.

Test C: Add 100 ppm of TSPP solution
Mix 30 seconds at 120 rpm
Add 200 ppm of Calcium Chloride solution
Mix for 30 seconds at 120 rpm
Adjust pH to 8.5 with sodium hydroxide solution
Mix for 30 seconds at 120 rpm.
Allow to stand and precipitate for five (5) minutes.
Filter through # 40 Whatman paper and retain filtrate for metals analysis
Acidify and refrigerate retained samples
Ship to Lancaster Laboratories for cadmium and lead determination.

Notes:

- Each test was conducted with 500 ml of sample, unless noted otherwise.
- Initially a 2:1 ratio of calcium to phosphate was selected to insure that the reaction was driven to completion. The desired crystalline end product is: $Ca_5(PO_4)_3(OH)_4$
- Calcium chloride dose modified to compensate for impact of iron phosphate formation.
- Each test was post treated with 10 ppm of anionic polyacrylamide copolymer to induce particle agglomeration and enhance filtration.

Sample OS:

Test A:

14.5 ppm of known metals present in sample

Dose with 0.1 ml of TMT-15 = 30 ppm active Trimercaptotriazine

Initial pH = 3.09
pH after TMT addition = 3.59

Test B: Adjust pH with 5% solution of sodium hydroxide

Add 1 cc of 5% sodium hydroxide: pH increases to 7.27
Add an additional 0.38 cc: pH = 8.52

Visible Pinfloc: Probably iron hydroxide

Add 0.1 cc of TMT-15 (30 ppm active ingredient): pH = 8.62

Stronger, more voluminous floc generated compared to Test A.

Test C: Add 2 cc of 5 % TSPP and mix: pH = 4.41
Add 1 cc of 5% $CaCl_2$ and mix: pH = 4.46
Increase pH to 8.5 with 5 % sodium hydroxide
Add 0.5 cc: pH =8.30
Increase dose to 0.58 cc: pH = 8.56

Pinfloc visible after pH adjustment.

Sample SS:

Test A:

TMT demand calculated at 458 ppm active ingredient

Note: Test volume = 700 ml.

Dose with 2.2 ml of TMT-15 = 471 ppm active Trimercaptotriazine
Mix

Initial pH = 5.25
pH after first TMT addition = 9.25

Creates suspended colloidal solids: Difficult to precipitate

Increase TMT dose by 1.0cc: Total concentration now = 685 ppm a.i.

Iron in filtrate = 6.70 ppm

Test B: Adjust pH with 5% solution of sodium hydroxide

Add 0.5 cc of 5% sodium hydroxide: pH = 5.45
Increase to 1 cc of 5% sodium hydroxide: pH increases to 9.25

Sample is not buffered.

Add 3.2 cc of TMT-15:

Colloidal, turbid solution: No pinfloc
Iron in filtrate = 1.80 ppm

Test C: Modify procedure: Add 1 pt of TSPP per part of iron in sample
Add 100 ppm of TSP to remove cadmium and lead.

Add 1.3 cc of 5 % TSPP (100 ppm) for cadmium and lead
Add 0.5 cc TSPP (30 ppm) for iron
Add 2.6 cc of 5% $CaCl_2$ and mix: pH = 6.35

Add 0.65 cc of 5 % sodium hydroxide: pH =9.26

Iron in filtrate = 0.33 ppm

Precipitates easily after anionic polymer addition:
Generates crystal clear water

Sample SD:

Test A:

TMT demand calculated at 1218 ppm active ingredient

Note: Test volume = 700 ml.

Dose with 22 ml of TMT-15 = 4714 ppm active Trimercaptotriazine
Mix

Massive, voluminous black floc
TMT: Metal ratio = 4:1: Too much TMT.

Initial pH = 3.04
pH after first TMT addition = 7.05

Note: Filtrate discolors: Reacts with nitric acid when sample is fixed: Indicates excess TMT.

Iron in sample reported as 296 ppm
Iron in filtrate = 135 ppm

Test B: Adjust pH with 5% solution of sodium hydroxide

Add 19.2 cc of 5% sodium hydroxide: pH = 8.48

Add 11 cc of TMT-15:

Iron in filtrate = 0.17 ppm

Test C: Modify procedure: Add 1 pt of TSPP per part of iron in sample
Add 100 ppm of TSP to remove cadmium and lead.

Add 8.4 cc of 5 % TSP pH = 3.33
Add 16.8 cc of 5% $CaCl_2$ and mix: pH = 3.22

Add 18.7 cc of 5 % sodium hydroxide: pH =8.54

Iron in filtrate = 3.20 ppm

Sample KDR:

Sample pH = 2.88
Sample iron = 52 ppm (GFR test) Reported as 78 ppm.

Volume for all three tests = 700 ml.

Test A:

TMT demand calculated at 770 ppm active ingredient

Dose with 4.5 ml of TMT-15 = 964 ppm active Trimercaptotriazine Mix

Large floc with clear water

pH after TMT addition = 4.70

Iron in filtrate = 13.5 ppm

Test B:

Add 3.25 cc of 5% sodium hydroxide: pH = 8.62

Add 3.8 cc of TMT-15: pH = 9.39

Iron in filtrate = 0.26 ppm

Test C:

Add 2.2 cc of 5 % TSPP (152 ppm) pH = 2.85
Add 2.9 cc of 5% $CaCl_2$ (200 ppm): pH = 2.84

Add 4.0 cc of 5 % sodium hydroxide: pH =8.75

Iron in filtrate = 0.18 ppm

Results:

Sample	Test	Cadmium ppm	Lead ppm
SS	Control	0.0091	0.0710
	Test A	0.0053	0.0263
	Test B	<0.0050	<0.0150
	Test C	<0.0050	<0.0150
KDR	Control	0.0793	<0.0150

	Test A	<0.0050	<0.0150
	Test B	<0.0050	<0.0150
	Test C	<0.0050	<0.0150
OS	Control	no test	no test
	Baseline	0.0040	0.3800
	Test A	0.0070	0.3200
	Test B	<0.0050	<0.0150
	Test C	<0.0050	<0.0150
SD	Control	0.1970	< 0.0750
	Test A	<0.0250	< 0.0750
	Test B	<0.0250	< 0.0750
	Test C	<0.0250	< 0.0750

Relative application costs:

Cost comparisons were made between:

Treatment A: Organosulfur
Treatment B: Organosulfur with pH adjustment
Treatment C: Trisodium polyphosphate

The results for Groundwater source SD and SS were evaluated.

- All three treatments worked effectively on Groundwater Source SD
- Trisodium Polyphosphate was more effective for removing lead and cadmium from Groundwater Source SS

Treatment cost per 1000 gal. of groundwater

Treatment	SD	SS
A: OrganoSulfur	$ 488	$ 11
B: Organosulfur with pH adjustment	$ 252	$ 72
C. Sodium Tripolyphosphate	$ 9	$ 1

Cost Basis:

Sodium tripolyphosphate supplied in dry bulk shipments at $ 42.00/CWT	($ 0.42/lb.)
Calcium chloride supplied in dry, bulk shipments at $ 182/ton:	($ 0.09/lb.)
Sodium hydroxide supplied in 330 gal. tote bin containers, at 25% solution strength at $ 14.25/CWT:	($ 0.1425/lb.)
Degussa TMT-15 supplied in semi-bulk, 275 gal. tote bin containers at:	($ 1.87/lb.)

Conclusion:

As expected both phosphate and sulfide precipitation remove cadmium and lead from solution.

The four test water sources each contain relatively low concentrations of lead and cadmium, which makes trend analysis somewhat difficult. Results with phosphate removal are more concise than with sulfide removal.

Cost wise, phosphate precipitation is clearly more effective than organosulfur. There are less expensive chemical sources of sulfide, however these have a host of application associated difficulties, as detailed within this report.

The study only addresses the issue of effective precipitation. One assumes that the lead and cadmium are interculated within the calcium phosphate crystalline lattice, and thus, effectively demobilized. Further study is required to verify this assumption.

Thank you for the opportunity to be of service to CSI, Inc. Please contact me with questions regarding this study.

Regards,

Gary Richards
WRT Services, Inc.

WRT Services, Inc. **1317 Pennsridge Court** **Downingtown, PA 19335**
Phone 610-873-6894 **Fax 610-873-3967** **WRT1997@aol.com**

APPENDIX F
Permeable Reactive Barrier Example Studies

- *In-vitro extraction test*, a simplified PBET using an aqueous solution to simulate gastrointestinal fluid into which contaminated soil is introduced.

ERTC worked with field staff to demonstrate use of these TPM's for evaluating organic-amendment technology at mining sites in Leadville, CO, Jasper, MO, Kellogg, ID, Picher, OK, and Prescott, AZ. Although regulatory concurrence on technology effectiveness varies, consistent application of TPMs allows for efficiency comparisons across similar technologies involving similar costs. EPA is working with other organizations such as the Interstate Technology and Regulatory Council to establish cost-effective and consistent protocols for using these TPMs.

Contributed by Harry Compton, U.S. EPA ERTC (compton.harry@epa.gov or 732-321-6751), Mark Sprenger, U.S. EPA ERTC (sprenger.mark@epa.gov or 732-906-6826), and Scott Fredericks, U.S. EPA Office of Solid Waste and Emergency Response (fredericks.scott@epa.gov or 703-603-8771)

PRB Containing Processed Fish Bones Sequesters Metals from Ground Water

Over the past decade, the U.S. Department of Defense, U.S. EPA, and other government or academic agencies sponsored demonstrations employing biogenic apatite as a reactive agent for remediation of soil and ground water. Early applications involved circulating pumped ground water into treatment tanks containing processed fish bones (known as Apatite II™) or the direct mixing of apatite into soil (see the March 2002 issue of *Tech Trends*, online at http://www.cluin.org/products/newsltrs/ttrend/archive.cfm). More recently, apatite served as the reactive medium in a PRB demonstration at the Success Mine and Mill site in northern Idaho. Evaluation of the system's performance over four years indicates that the PRB reduced concentrations of target metals in ground water 99%, significantly above the anticipated 75% reduction, but experienced difficulty maintaining a constant flow of water.

The PRB was installed in 2001 to address leaching of metals from approximately 500,000 tons of mine tailings at a former disposal area adjacent to a tributary of the Coeur d'Alene River. Below the tailings, an alluvial layer extends to bedrock at 16-20 feet bgs. Investigations indicated that soil contained lead, zinc, and cadmium in concentrations ranging from 1,000 to 4,000 mg/kg. Ground-water and surface seeps also contained elevated concentrations of the metal leachates, reaching 1.25 mg/L for cadmium, 1.44 mg/L for lead, and 177.0 mg/L for zinc.

Biogenic apatite was selected as the reactive medium due to its ability to stabilize metals in water through precipitation, co-precipitation, sorption, or biological stimulation. In addition, the organic carbon in apatite could serve as both an electron donor and carbon source for sulfate-reducing bacteria that accelerate precipitation of metal (particularly zinc) sulfides directly onto the reactive medium surface. Based on the results of bench-scale tests performed by the Idaho Department of Environmental Quality (IDEQ), fish-bone apatite was selected for the PRB rather than alternate forms such as synthetic hydroxyapatite, mineral

apatite from phosphate rock, or cow bones.

Construction of the PRB involved excavation of a 15-ft-wide trench extending 14 feet bgs and 50-ft-long and between the tailings pile and creek. The trench was lined with type-V Portland cement in a baffled pattern to create a two-cell vault that would uniformly receive seep and alluvial ground-water flow. Each cell contains five 6-ft-wide, 9-ft-long chambers separated by plywood baffles that bring ARD into optimal contact with the reactive medium. Both cells were filled with 100% Apatite II.

The vault was plumbed and valved to allow sampling and potential replacement of the reactive media. A 1,200-ft grouted containment wall and hydraulic drain were installed upgradient of the PRB to divert water to the treatment vault while reducing migration of any contaminants bypassing the system. Captured ARD flows from the drain through underground piping and into the vault, where the water is split and piped into each of the two cells for parallel treatment. Upon exiting the vault, treated water discharges to a rock apron that routes it into the nearby creek. Water passes through the vault at a rate of approximately 5 gpm, resulting in a total residence time of approximately 24 hours.

After a year of operation, one of the cells exhibited plugging. A 1:1 mixture of pea gravel and apatite was mixed into the cell to increase porosity and the rate of treatment flow. Data collected over four years of monitoring indicate that water exiting the PRB contains lead and cadmium in average concentrations below the detection limits of 0.005 mg/L and 0.002 mg/L, respectively. Zinc concentrations also decrease as a result of treatment, to below the average background level of 0.100 mg/L. Concentrations of these metals in the effluent consistently meet the State of Idaho criteria for drinking water. In addition, pH of the water increases from 4.5 before treatment to 6.5-7.0 upon exiting the PRB. Slightly elevated concentrations (approximately 10 ppm) of chemical byproducts such as ammonia and phosphate exist in water exiting the vault but decrease after passing through the rock apron.

Sample analysis also shows that water entering the vault contains an average sulfate concentration of 250 mg/L, while sulfate in water exiting the system ranges from 35 to 150 mg/L. X-ray diffraction analysis performed by Idaho National Laboratory (INL) confirmed high concentrations of sulfate in precipitates formed in the media. Detailed analyses of microbial communities within the PRB suggest that sulfate-reducing *Enterococci* bacteria are the primary drivers of sulfate reduction in the ARD. Analysis of the treated water indicates that these microbial populations do not exist in the system effluent. Changes in key ground-water parameters indicate that a corresponding increase in metal precipitation is caused by the sulfate-reducing bacteria within the PRB (Figure 3).

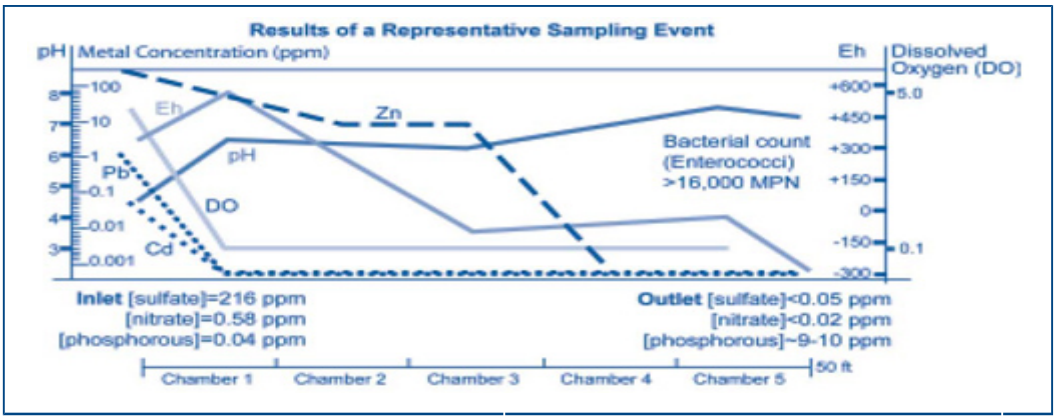

Figure 3. Changes in key ground-water parameters within the Apatite II PRB indicate that pH of the ARD is buffered during treatment and that metals are sequestered from ARD primarily within the first two treatment chambers.

Although influent initially entered the PRB at a rate of approximately 30 gpm, it quickly decreased to and remained at 5 gpm due to intake buildup of suspended alluvial silica and breakdown of the apatite. Subsequent system optimization conducted by researchers from INL and IDEQ involved replumbing of the intakes, which had little effect on the rate of treatment flow. In addition, INL injected air into both treatment cells during a single event last spring in order to aerate the apatite medium and to decrease overflow at both of the cell inlets. Air sparging resulted in a 7- to 15-fold temporary increase in treatment flow and cessation of the overflow. Overall results indicate that mixing of apatite with pea gravel did not improve the rate of treatment flow or decrease performance of the system.

A total of approximately 150 pounds of lead, 100 pounds of cadmium, and 10,000 pounds of zinc were sequestered in the vault during the demonstration, over 80% of which collected in the first two treatment chambers of both cells. As of mid 2005, field investigations suggested that about 40% of the barrier was spent. The reactive media consequently were removed from the apatite/gravel cell and disposed onsite as non-hazardous waste later in the year. The cell was re-filled with limestone in the first chamber and a mixture of apatite and plastic packing rings (to provide additional aeration) in the remaining four chambers.

Due to its extremely high concentrations relative to lead or cadmium, zinc is expected to serve as the indicator of PRB break-through. Longevity of the PRB will depend upon the ability to reduce system plugging and maintain an adequate rate of treatment flow. Construction of the PRB cost more than $500,000, including $35,000 for 100 tons of Apatite II.

Similar performance results were demonstrated for an apatite PRB at the Nevada Stewart Mine Site near Wallace, ID, where routine air injections are performed to reduce system plugging. Animal toxicity studies conducted by the IDEQ at that site (using the invertebrate *Ceriodaphnia dubia* and the fathead minnow

Pimephales promelas,) demonstrated complete toxicity removal for both species from contaminated water that had passed through the PRB. Additional microbiological studies recently conducted at New Mexico State University (NMSU) suggest that apatite can induce biodegradation of contaminants such as perchlorate, TNT, and RDX.

Contributed by Bill Adams, EPA Region 10 (adams.bill@epa.gov or 206-553-2806), Neal Yancey, INL (neal.yancey@INL.com or 208-526-5157), James Conca, Ph.D., NSMU (jconca@cemrc.org or 505.706.0214), and Judith Wright, Ph.D., PIMS NW, Inc. (judith@pimsnw.com or 505.628.0916)

MWTP Demonstrates Integrated Passive Biological System for Treating Acid Rock Drainage

The U.S. EPA and U.S. DOE recently completed a four-year, pilot-scale demonstration of a passive biological system for treating ARD at the Surething Mine near Elliston, MT. Mining of gold, zinc, and lead at this mine from the late 1800's until the mid 1950's exposed sulfide mineralization to the environment, which led to ARD discharge from the mine adit. In addition to being highly acidic, the ARD contained elevated concentrations of iron, aluminum, copper, zinc, lead, arsenic, cadmium, and manganese. This demonstration was one of several sponsored by the Mine Waste Technology Program to identify effective source-control technologies for retarding or preventing acid generation at mining sites.

The technology's multi-stage process at the Surething Mine involved sequential passage of ARD from the mine adit through three adjacent anaerobic reactors and an aerobic reactor. Anaerobic treatment relied on sulfate-reducing bacteria that reduced dissolved sulfate to hydrogen sulfide, which reacted with dissolved metals to form insoluble metal sulfides. This bacterial metabolism also produced bicarbonates that increased pH of the ARD and limited dissolution of metal. Seven of the eight target metals were addressed through the anaerobic process.

The treatment system was constructed in the summer of 2001. It was designed to treat a maximum ARD flow rate of 2 gpm, although rates varied due to seasonal influences and reached 10 gpm during spring runoff. The first anaerobic reactor through which ARD passively flowed was constructed of a mixture of cow manure and walnut shells. Cow manure provided a source of easily degradable organic carbon and large populations of sulfate-reducing bacteria. The walnut shells provided a longer-term source of organic carbon and the structural strength needed to maintain permeability of the mixture. Bench-scale tests indicated that this initial reactor would successfully establish the sulfate-reducing conditions needed for the overall system, but also that it would be the first to fail due to bacterial incompatibility with the low pH of feed water. Sulfate-reducing capabilities also were challenged by the presence of iron ion in the ARD, 95% of which existed in the ferric state.

Drainage water then flowed passively through the second anaerobic reactor, which was constructed of limestone cobbles that added alkalinity to the water.

TREATMENT OF ACID MINE DRAINAGE USING FISHBONE APATITE II™ [1]

Neal A. Yancey[2] and Debby Bruhn[3]

ABSTRACT. In 2000, a reactive barrier was installed on the East Fork of Ninemile Creek near Wallace, Idaho to treat acid mine discharge. The barrier was filled with fishbone derived Apatite II™ [4] to remove the contaminants of concern (Zn, Pb, and Cd) and raise the pH of the acidic mine discharge. Metal removal has been achieved by a combination of chemical, biological, and physical precipitation. Flow for the water ranges from 5 to 35 gallons per minute. The water is successfully being treated, but the system experienced varying degrees of plugging. In 2002, gravel was mixed with the Apatite II™ to help control plugging. In 2003 the Idaho National Laboratory was ask to provide technical support to the Coeur d'Alene Basin Commission to help identify a remedy to the plugging issue. Air sparging was employed to treat the plugging issues. Plastic packing rings were added in the fall of 2005, which have increased the void space in the media and increased flows during the 10 months of operation since the improvements were made.

Additional Key Words: reactive barrier, heavy metals, mining.

---

[1] Paper was presented at the 2006 National Association of Abandoned Mine Land Programs 28th Annual Conference, September 25-27, 2006, Billings MT.

[2] Neal A. Yancey is a Senior Engineer in the Environmental Engineering Department, Idaho National Laboratory, Idaho Falls, Idaho 83415.

[3] Debby F. Bruhn is a Senior Scientist in the Biological Sciences Department, Idaho National Laboratory, Idaho Falls, Idaho 83415.

[4] Product Disclaimer:

References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government, any agency thereof, or any company affiliated with the Idaho National Laboratory.

BACKGROUND

The Coeur d'Alene Basin of Northern Idaho is known as Silver Valley because of the huge volume of silver mined in the area in the early 1900s. As a result, thousands of acres of land and miles of streams have been contaminated with metals from the mining and milling activity (Gillerman 2002). Stabilizing stream banks and tailings piles that are sources of sediment and particulate metals in the creeks is one cleanup activity that is being implemented in the Coeur d'Alene Basin. In some locations, tailings have been piled on the canyon floors and cover the original creek channels. Water now flows through the tailings, where it picks up dissolved and suspended metals (Figure 1). The Success Mine site was identified as the largest remaining source of metals loading in the Ninemile Creek drainage (EPA 2002). Zinc, cadmium and lead concentrations are significantly higher in this area than background areas. During high flows in the spring, sediments that were trapped during low flow periods are resuspended and carried downstream. The pH of the water is also lower in this area due to the presence of pyrite formations (Golder Associates Inc., 2002).

Figure 1.0 Ground and Surface Water Passing through Mine Tailings

Groundwater flows from the adjacent hillsides and comes up in various locations in the canyon floor. Portions of this water comes up through the tailings pile and flows down gradient until it enters the creek, again carrying with it increased levels of dissolved and suspended metals with a lowered pH level.

INTRODUCTION

In 2000, a 45 foot long 12 foot deep reactive barrier was constructed to treat acid mine drainage resulting from surface and groundwater passing through mine and mill tailings at the Success Mine on the East fork of Ninemile Creek near Wallace, Idaho. The reactive barrier was constructed having two separate sides, each 6 foot wide, 12 feet deep, and 45 feet long (See Figure 2). On each side of the reactive barrier, water flows over and under alternating baffles to

create as much contact between the media and contaminated water as possible. Each side of the reactive barrier has 5 cells separated by these alternating baffles (Figure 2).

The reactive barrier was filled with fishbone Apatite II™ as a media to remove the metal contaminants and to raise the pH of the water. Apatite II™, derived from fish bones, stabilized a wide range of metals, including Zn, Pb, and Cd (Write et al., 1995). Depending on the metal concentration and water chemistry, the Apatite II™ works by four possible processes: heterogeneous nucleation, pH buffering, chemisorption, and biological stimulation (Wright and Conca 2005). From the start, the reactive barrier successfully removed metals from the contaminated discharge, as well as early on, the system began experiencing plugging problems.

Figure 2.0. Construction of the Reactive Barriers at the Success Mine Site.

Gravel was added in 2001 to help control plugging. This provided only a short benefit and plugging was again an issue. The INL received funding in 2003 to assist the Coeur d'Alene Basin Commission in remediating the plugging issues associated with the reactive barrier. Chemical and biochemical analysis was performed on the media to determine the forms of metal precipitates, biological conditions, and physical and chemical conditions of the media.

In May of 2005, the compressed air was injected into the Apatite II™ to break up sediments deposited in the media in order to increase flow through the media. MSE Technology Applications, Inc., in Butte, Montana had demonstrated that injecting air into a similar reactive barrier at the Stewart Mine on Pine Creek had successfully increased flow in the Apatite II™ media at that location (McCloskey et al., 2006).

In November 2005, the old gravel/ Apatite II^{TM} mixture was removed and disposed onsite to make room for the new Apatite II^{TM} /plastic packing ring mixture. New Apatite II^{TM} media mixed with plastic packing rings was used to replace the plugged media in the East side of the reactive barrier. The plastic packing rings were used to increase the void space in the media and alleviate the plugging problem.

Material and Methods

Biological Analysis of the Apatite II^{TM} Media

The Apatite II^{TM} media was sampled to determine if sulfate reducing bacteria (SRB) were active in the barrier. These bacteria are responsible for precipitating metal ions found in acid mine drainage. SRBs are a ubiquitous group of prokaryotic microorganisms found in anaerobic environments. In the process of anaerobic respiration these organisms can use a variety of electron donors (AH_2) and can couple oxidation of those compounds to reduction of sulfate and elemental sulfur as shown in the following equation:

$$4\ AH_2 + SO_4^{-2} + H^+ \rightarrow 4\ A + HS^- + 4\ H_2O$$

It is in the anaerobic zone that the remediation takes place. The sulfide produced then precipitates with the soluble metals (such as Fe, Cu, Mn, Zn, Pb, and Cd) as insoluble metal sulfides, and the net consumption of protons due to formation of hydrogen sulfide gas generates bicarbonate alkalinity, which raises the pH of the waste stream.

The media used to isolate and identify SRB was Bacti control bottles API Anaerobic media which includes ammonium phosphate, dipotassium phosphate, yeast extract yeast extract, sodium lactate and magnesium sulfate and a nail to provide iron manufactured by Sherry Laboratories. Water samples were collected from each cell in both sides of the reactive barrier and from the outflow. One mL of each water sample was injected into a Bacti vial, using sterile methods. Each sample was collected in triplicate and diluted out to 10^{-8}. Medium used for heterotrophic and enteric bacteria was 2% PTYG Agar (2% Peptone-Tryptone-Yeast Extract-Glucose and 1.5 % agar) and Luria-Bertani Agar (10 g tryptone, 5 g yeast extract, 5 g NaCl, and 15 g agar per liter of water). One mL and 0.1 mL samples were plated in duplicate on both medium. Eh and pH of water samples were also taken.

Chemical Analysis of the Apatite II^{TM} Media

Apatite II^{TM} samples were collected from below the water level in each side of the reactive barrier to be representative of the conditions where chemical and biological reactions occur. The samples were collected and stored in polypropylene containers and put on ice until they were received at the laboratory.

Both the sediments and the Apatite II™ were oven dried for 24 hours at 90º C. The samples were sieved to separate the sediments from the Apatite II™ media. The Apatite II™ media was also washed with tap water (tap water) to remove any surface attached material from the fish bones. The samples were pulverized with a mortar and pestle in preparation for analysis. The samples were analyzed for both metal concentrations and speciation using Powder X-Ray Diffraction and XRF and by Scanning Electron Microscopy.

Injection of Compressed Air to Improve Flow

The covers to the reactive barriers were removed to provide access to the media. A 10 foot galvanized hollow wand was fabricated to inject compressed air deep into the media. Compressed air was injected in at least two locations in each of the 5 cells for both the East and West side of the reactive barrier (See Figure 3).

Figure 3. Injecting Compressed Air in the Apatite II™ Media.

Replacing the Media in the Reactive Barrier with Apatite II™ and Plastic Packing Rings

Attempts to improve flow on the East side of the reactive barrier were only temporarily successful. The addition of gravel to the media did not improve flow through the system. Aerating the Apatite II™ media was successful for a short time, but it soon returned to the original flows. As a result, an alternative mixture of Apatite II™ and plastic packing rings was used to help increase the percent of void space in the reactive barrier. Plastic packing rings (produced by Jaeger Products Inc.,) are used in many aspects of water treatment to increase the

surface area for microbial attachment and increase the reactive area of the media. They are also used to increase the void space in the media (Figure 4).

Figure 4. Plastic Packing Rings.

Results and Discussion

Water samples were taken at the discharge of both sides (East and West) of the reactive barrier to determine if SRBs were present in the discharge. Water was also sampled in each of the 5 cells on each side of the reactor. The Apatite II™ was plugged on the East side and required mechanical mixing and injection of compressed air to get water flowing again through the reactive barrier. This would have affected the true Eh values being measured in the field at the time. Table 1 shows the results of the field measurement for pH and Eh and Table 2 shows the laboratory results for the SRB counts.

Table 1. Field Measurements for Eh, pH, and SRB Counts.

Sample	Eh	pH
Inflow water	468	4.5
Cell 1 West	211	7
Cell 2 West	-48	6
Cell 3 West	245	6
Cell 4 West	238	6
Cell 5 West	-199	7
Outflow West	150	7
Cell 1 East	236	6
Cell 2 East	310	6
Cell 4 East	Not sampled	Not sampled
Cell 5 East	Not sampled	Not sampled
Outflow East	224	7
E.fork Nine Mile Creek	550	

Table 2. Sulfate Reducing Bacteria Counts.

Sample	Sulfate Reducing Bacteria
Cell 1 West	3×10^4 /mL
Cell 2 West	3×10^4 /mL
Cell 3 West	4×10^4 /mL
Cell 4 West	4×10^3 /mL
Cell 5 West	7×10^5 /mL
Outflow West	1×10^2 /mL
Outflow West	present
Cell 1 East	1×10^5 /mL
Cell 2 East	7×10^3 /mL
Cell 3 East	Not Done
Cell 4 East	1×10^3 /mL
Cell 5 East	7×10^3 /mL
Outflow East	1 /mL
Outflow East	Present

The most obvious finding is that there was in fact SRBs present in the reactive barrier as expected, so some treatment (precipitation) of should occur. The Eh values indicate that most samples are not anaerobic (negative value). This is probably due to the low levels of water in the barrier, which was a consequence of the time of year and weather conditions. Several locations in the West cells had negative Eh values, indicating that the water was deep enough in the barrier and anaerobic activity was present. However, not all location in the West cells had negative Eh values. The micro anaerobic zones did exist throughout the barrier, as shown by the presence of SRB's in most samples. If more water was present in the barrier, a larger anaerobic zone could be created and a larger population of SRB would be present (1×10^8 /mL). This would hopefully lead to complete precipitation of the metal and an increase of the pH to neutral (7.0). The East cells had little to no water flow and no anaerobic zones as indicated by the positive Eh values. It is not likely that treatment was occurring in this cell. If flow can be maintained, and anaerobic zones created, SRB should grow and metal precipitation and pH increase should occur.

Chemical Analysis of the Apatite II™ Media

The presence of zinc, cadmium and lead were measured in the Apatite II™ using scanning electron microscopy (SEM). The SEM provided a relative concentration for each metal. Figure 5 shows the relative weight percents observed in the Apatite II™ for each of the metals of concern. In addition, the concentration of sulfur was also measured. Sulfate is present in the feed water. Under anaerobic conditions, the metals form insoluble sulfide precipitates. The presence or absence of sulfur can be used to determine if metal sulfides are being formed under the conditions present in the reactive barrier. In the Apatite II™ samples, there was no appreciable amount of sulfur detected (Figure 5).

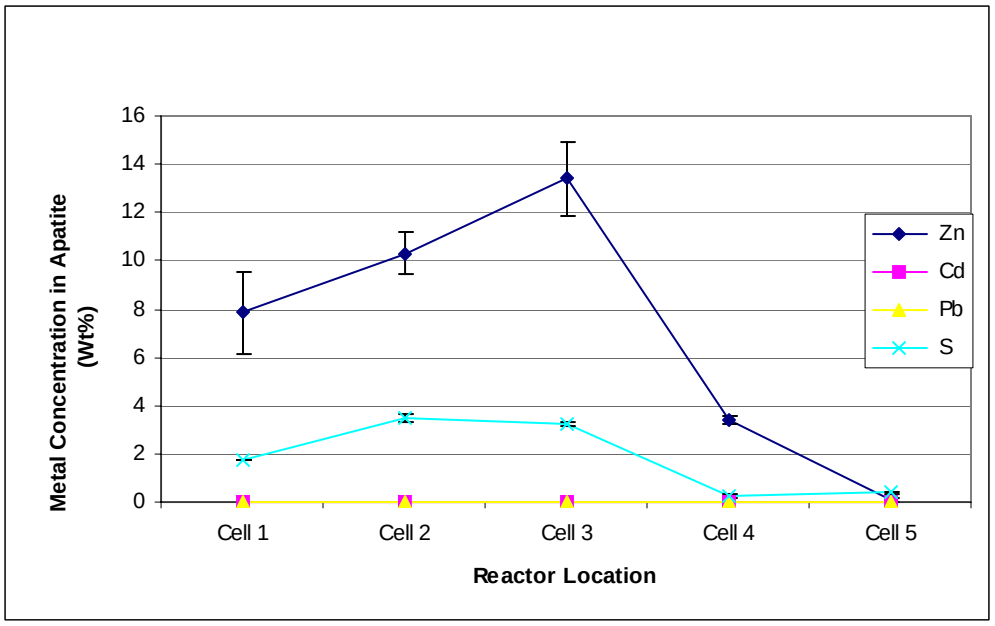

Figure 5. Metal concentration in the Apatite II^{TM} material from the West Side of the Reactive Barrier.

The sediments around the Apatite II^{TM} were also analyzed for metal concentration. Slightly higher concentrations of zinc and lead were present in the sediment than in the Apatite II^{TM}. There was also a notable amount of sulfur present in the sediment. This suggests that the metal precipitates formed in the sediments were resulting at least in part due to metals sulfides being formed under anaerobic conditions.

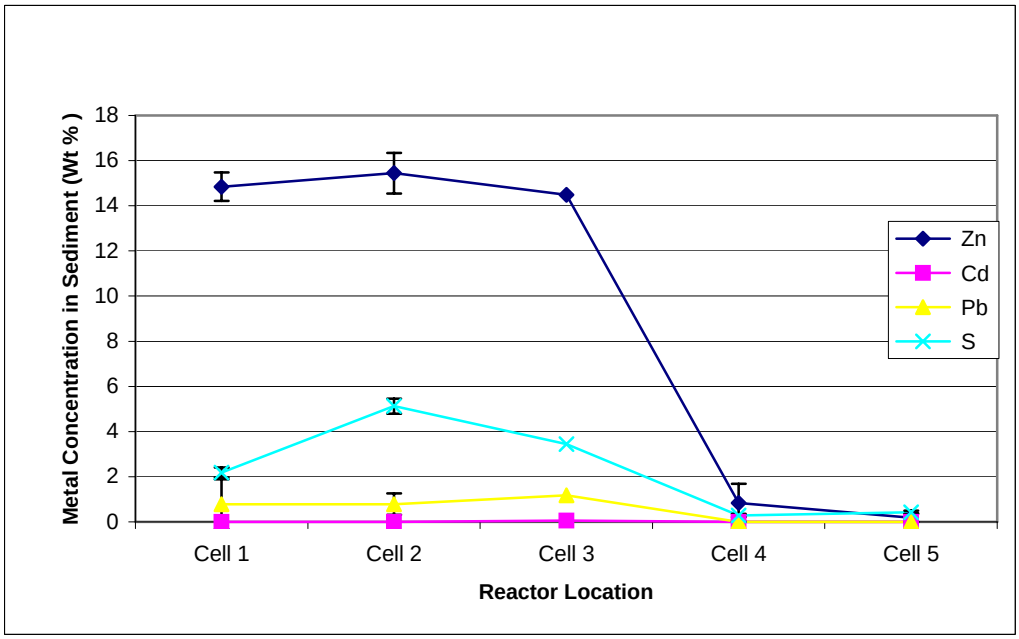

Figure 6. Metal concentrations in the sediment of the West Reactive Barrier.

The same analysis was performed on the East side of the reactive barrier. Figure 7 shows the zinc, cadmium, lead and sulfur concentrations found in the Apatite II^{TM} from the East side of the reactive barrier. This figure shows that the concentrations of the contaminant metals were lower in the East side than the West side. It also shows that most of the reaction occurs in the first two cells and that the subsequent cells are not removing metal from the contaminate water.

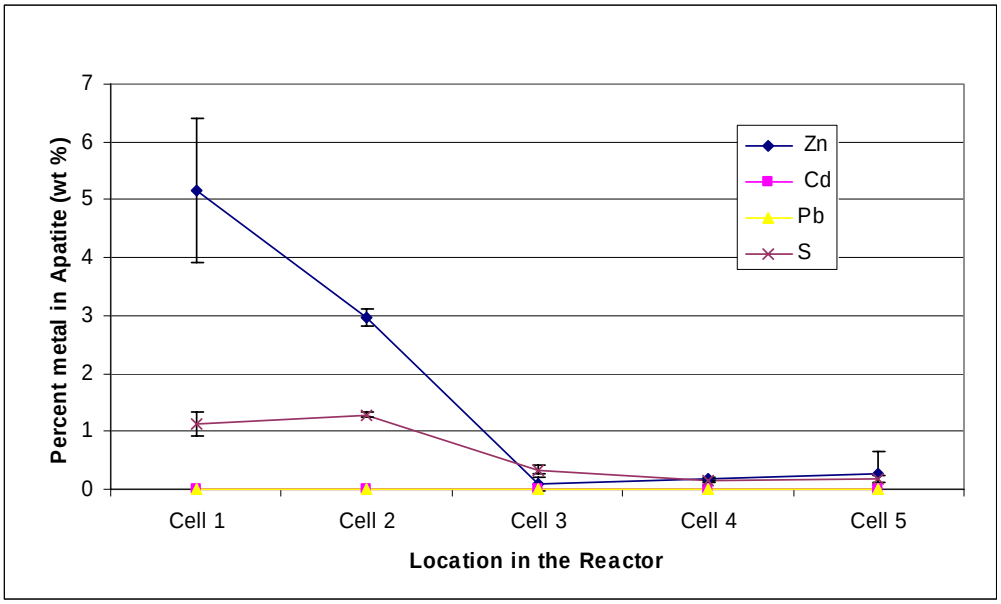

Figure 7. Metal concentration in the Apatite II^{TM} from the East side of Reactive Barrier.

Figure 8 illustrates the concentrations of the metals of interest in the sediment of the East side of the reactive barrier. Most of the precipitation that does occur, takes place within the first two cells of the barrier. The concentration is about half the measured values observed in the West side of the reactive barrier.

Injection of Compressed Air

The reactive barrier was constructed in 2000 and the first Apatite II^{TM} was placed in the barrier in January of 2001. Other than adding new media to the East side of the reactive barrier in 2002, nothing had been done to deal with the plugging issues associated with the reactive barrier. The cause of the plugging was a combination of sediment buildup from the influent stream and sedimentation occurring from the breakdown of the Apatite II^{TM}. Figure 9 illustrates the sediment buildup that had occurred in the West side of the reactive barrier. Note the buildup of sediment in the Apatite II^{TM} and notice how the water has formed preferential paths in the media resulting in inefficient contact of water and the reactive media.

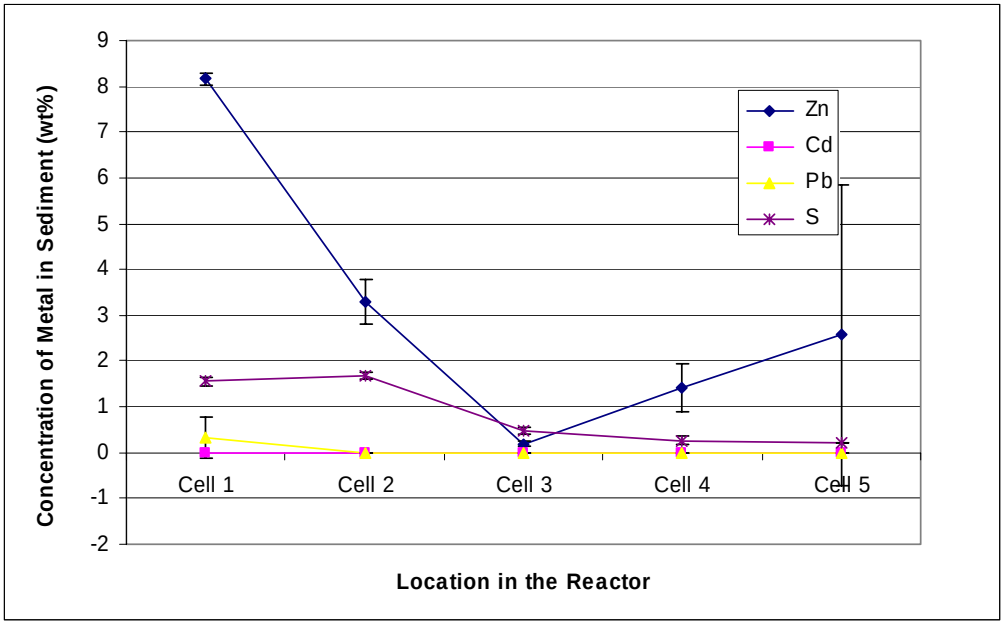

Figure 8. Metal Concentration in the Sediment of the East side of the reactive barrier.

Another similar site in the Coeur d'Alene basin is using Apatite II^{TM} to treat acid mine drainage at the Nevada Stewart Mine. At this location, compressed air is injected into the media combat the effects of plugging on the reactive barrier. This results in temporarily increased flow in the media at the Nevada Steward Mine site. For the reactive barrier at Success, a ten-foot hollow wand was constructed to inject air deep into the media at the Success Mine reactive barrier. Figure 10 shows the workers injecting air into the media at the Success Mine.

Figure 9. Sediment buildup in the Reactive Media.

Figure 10. Injection of Compressed Air into the Reactive Media.

The result of the injection of compressed air into the media was an immediate increase in flow through the reactive barrier, primarily on the West side. The presence of the gravel on the East side made it difficult to get the metal wand into the media to successfully inject the air into the media. This resulted in only limited success on the East side of the reactive barrier.

Figure 11 shows the flow rate measured at the discharge of the reactive barrier. Note that before injecting air into the reactive media, there was a steady stream of water measured in the overflow for the system. Following the air injection, the flow through the reactive media increase and the overflow went to zero meaning that the system was again treating all of the water. The flow rates in general continued to decrease over time following the air injection, but this is primarily due to a seasonal decrease in flow. Note that there was no flow observed in the overflow following the air injection and that the flow in the West side increased again in the Spring of 2006 when flows came back up. Flow on the East side also increased at that time, but it should be noted that the increase in flow on the East side could be directly attributed to the addition of new media in November of 2005. From this it can be observed that injecting compressed air into the media does provide at least temporary improvement to flow in the Apatite II^{TM} media.

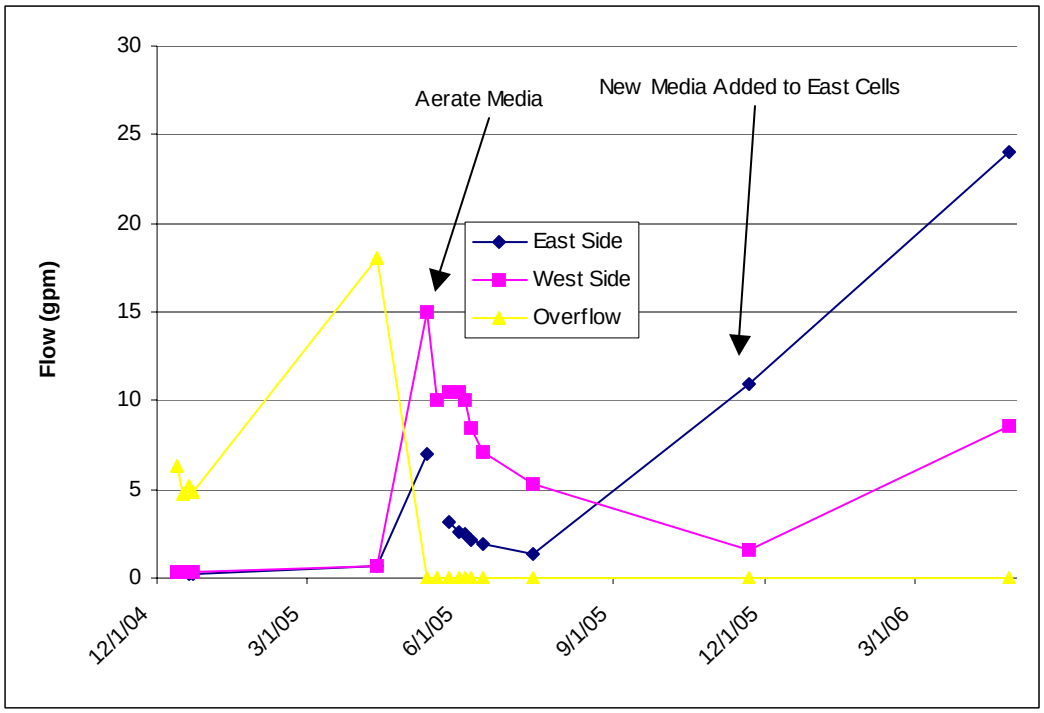

Figure 11. Flow rates measured in the outlet and overflow of the reactive barrier.

Replacing the Media in the Reactive Barrier with Apatite II^{TM} and Plastic Packing Rings

In November of 2005, the media in the East side of the reactive barrier was replaced with new Apatite II^{TM} mixed with plastic packing rings at a ratio of 30 volume % plastic packing rings. Two inch Jaeger plastic packing rings were used to provide an increase in void volume in the reactive barrier. The increase in void volume was desired to provide more area for water to flow through in the Apatite II^{TM} media and to provide more volume for sediments and precipitates to form without impacting the flow. Figure 4 is a picture of the packing rings used in the reactive barrier. By themselves, the plastic rings have a void volume of 92%. Information on the void space of Apatite II^{TM} was not available, but had noticeably less void volume than the plastic rings alone.

Prior to the removal of the old Apatite II^{TM} /gravel mixture and the placement of the new Apatite II^{TM} /plastic packing ring mixture, the flow from the East side of the reactive barrier was less than 1.5 gallons per minute. After replacing the media, the flow increased to over 10 gallons per minute in December of 2005. It further increased to 24 gallons per minute in April of 2006 (primarily due to high Spring water runoff). This is the highest flow produced from the East side of the reactive barrier since it was constructed. In June of 2006 the flows had gone back down to just over 5 gallons per minute, but there was no water flowing out the overflow. This still was the highest flow from the East side of the reactive barrier since May of 2002. Figure 12 illustrates the flow rates through the reactive barrier since it was constructed. Since the change out of the

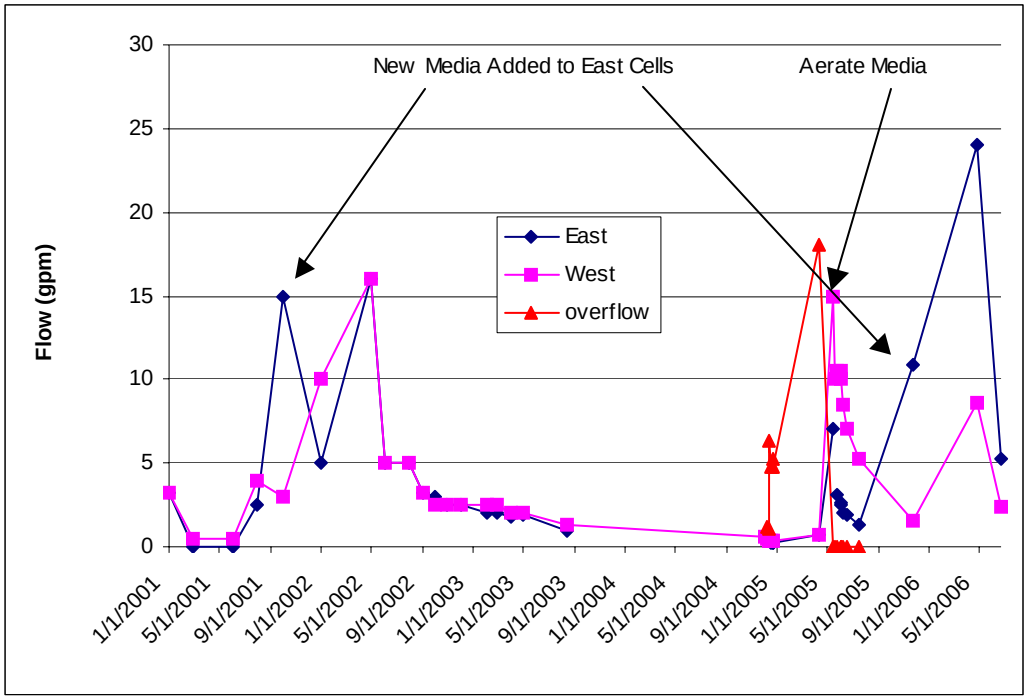

Figure 12. Flow rate (gallons per minute) for the Success Reactive Barrier.
*data from 1/1/2001 to 9/1/2003 was taken from Golder 2003 – overflow data was not always collected

media in the fall of 2005, the East side of the reactive barrier has produced higher discharge flow rates than the West side of the reactive barrier for a longer period of time since the barrier was constructed.

Ph was measured from November 2004 through September of 2005. The pH of the water has been improved by treatment with the Apatite II^{TM} media. Influent pH levels average 4.8. Effluent pH values average 6.7 in the West side of the reactive barrier and 6.6 from the East side of the reactive barrier.

Removal efficiency

The average concentration of the metals of concern in the influent to the reactive barrier are 0.52 mg/L Cd, 1.01 mg/L Pb, and 83.6 mg/L Zn. The average concentration in the discharge for the West side of the reactive barrier is 0.007 mg/L Cd, 0.014 mg/L Pb, and 1.06 mg/L Zn. On the East side of the reactive barrier the outlet average outlet concentration is 0.002 mg/L Cd, 0.005 mg/L Pb, and 0.374 mg/L Zn. The removal efficiencies for the metals are presented in Figure 13. In each case, the removal efficiency is greater than 98% removal.

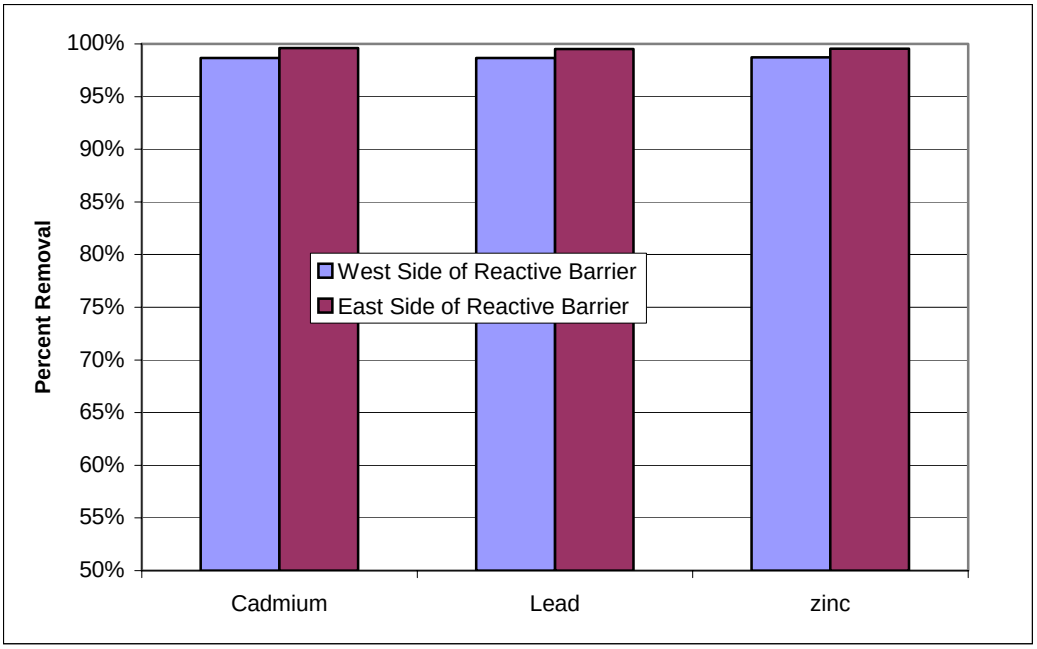

Figure 13. Removal Efficiency for Cd, Pb, and Zn from the Reactive Barrier.

Summary

The biological and chemical analysis of the Apatite II™ showed that the reactive barrier is utilizing more than one single method to remove metal contaminants from the mine drainage, specifically both biological reduction and chemical sorption are causing the reduction in metal concentrations in the contaminated waters.

The injection of compressed air does improve the performance of the reactive barrier by breaking up preferential flow paths created over time in the media. The process of injecting compressed air will need to be reviewed on a case-by-case basis, but in this case annual injection of air would lengthen the life of the media.

Since the construction of the reactive barrier in 2001, the media in the East side of the reactive barrier has been replaced twice. It is not clear why the problem started so early on in the system when both sides of the barrier appeared to have been constructed in the same manner. It is apparent that mixing the Apatite II™ with gravel does not improve the efficiency of the system. Two problems resulted from this. First, the addition of gravel to the Apatite II™ did not have the desired effect of increasing the void space of the media; it simply reduced the amount of media present. Second, it created a media with a much higher bulk density. The two sides appear to have similar void volumes. Water entering the two sides of the reactive barrier enters from the same distribution box or manifold. Water naturally tends to flow to the path of least resistance which in this case is the side without the gravel.

Since the new Apatite II™ mixed with plastic packing rings was put in the East side of the reactive barrier in November 2005, the flows in the East side of the reactive barrier have surpassed the West side for the longest period of time since construction. While continued monitoring needs to take place, we are optimistic that this will be a beneficial solution to the plugging experienced at the Success Mine.

Using the average flow rates and average concentrations in the source water and the treated water, it is estimated that the system has removed 44 pound of cadmium from the East side and 49 pounds of cadmium from the West side of the reactive barrier, 85 pounds of lead from the East side and 95 pounds of lead from the West side of the reactive barrier, and 7003 pounds of zinc from the East side and 7850 pounds of zinc from the West side of the reactive barrier over the 5 years of operation. While this paper discusses resolving plugging issues with the Apatite II™ media, it should be noted that the systems has continued to successfully reduce metal concentrations in acid mine drainage to below drinking water standards and raise the pH to near neutral levels. With the addition of the plastic packing rings to the Apatite II™, it is anticipated that the system will continue to operate for several more years.

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APPENDIX G
Aquifer Test Date [GeoSyntec, 2000]

Prepared For:

INTERIM PEDRICKTOWN SITE GROUP

PHASE II GROUNDWATER EVALUATION TECHNICAL MEMORANDUM

NL INDUSTRIES, INC. SUPERFUND SITE

PEDRICKTOWN, NEW JERSEY

Prepared By:

GEOSYNTEC CONSULTANTS
10015 Old Columbia Road, Suite A-200
Columbia, Maryland 21046

Project Number ME0015-15
January 2000

9. AQUIFER TEST

9.1 Overview

In 1983, Geraghty & Miller performed an aquifer test at the NL site. The EPA questioned some of the techniques used in Geraghty & Miller's evaluation and required the Group to perform an aquifer test. This section includes a description of the aquifer test performed in June 1999 by GeoSyntec. The aquifer test was conducted to: (i) confirm the hydraulic parameters determined by Geraghty & Miller in 1983; (ii) predict the performance of a groundwater extraction system that might be designed to remove lead and cadmium from the aquifer; and (iii) establish input parameters for capture zone modeling as requested by the EPA.

Aquifer parameters have been estimated based on the results of the aquifer test completed in June 1999. Standard analytical methods were employed in the analysis of the aquifer test data to determine transmissivity, hydraulic conductivity, and storativity. AQTESOLV™ for Windows™ (HydroSOLVE, Inc., 1999) was used to perform the analyses. The hydraulic parameters, combined with other site-specific data such as average grain size, depth to the underlying clay layer, saturated thickness, etc., were used to refine the conceptual hydrogeologic model of the site originally presented in the *Phase I Groundwater Evaluation Technical Memorandum.*

The aquifer testing included ambient water-level monitoring, a variable-rate pumping test (step test), and a 72-hour constant-rate pumping test. Groundwater was pumped from pumping well PW, a six-inch diameter, fully-penetrating well installed and developed for the conduct of this aquifer test. Drawdown was measured in several nearby wells throughout the testing process, including observation well OW, the nearest well to pumping well PW. The relative locations of PW, OW, and all other observation wells used during the test are presented on Figure 9-1. Boring logs are provided in Appendix A for each of the new wells at the site. The following subsections describe the aquifer testing procedures and present the analysis of the results.

9.2 Procedures

9.2.1 Ambient Water-Level Monitoring

Prior to the on-set of aquifer testing, passive water-level monitoring was conducted using PXD-60 pressure transducers and a Hermit datalogger manufactured by In-Situ, Inc. This monitoring was conducted for approximately 13 days beginning on 20 May 1999 and measurements were collected once per hour. Measurements were obtained from six wells including: PW, OW, 27, 28, KS, and KD. Figure 9-2 shows a hydrograph throughout the 13-day monitoring period at observation well OW. After approximately 95 hours of monitoring, at approximately 12:30 p.m. on 24 May 1999, the water level began to rise in Well OW, increasing approximately one foot over a 13-hour period. This increase in water level was also evident in the other wells monitored. This rise was coincident with an 11-hour precipitation event that included more than two inches of rain over the area (precipitation data derived from Wilmington, Delaware weather station, NOAA, 1999). Following the peak water level, the head in the wells gradually declined toward the seasonal low, approaching static conditions just prior to the step test.

GeoSyntec obtained additional ambient water-level data after the step test and constant-rate test were completed to further evaluate the characteristics of the aquifer. This monitoring began on 23 July 1999 and continued through 9 August 1999. The hydrograph for pumping well PW is shown on Figure 9-3. The graph indicates a steady decline in the water table as no precipitation occurred during the monitoring period. The decline is approximately 0.04 feet per day, with diurnal fluctuations of approximately 0.02 feet. The diurnal peaks generally occur between 3:00 and 4:00 am and the diurnal troughs generally occur between 8:00 and 10:00 p.m. Figure 9-4 shows the first 4,500 minutes of this monitoring period in greater detail.

9.2.2 Step Test

After obtaining the pre-test ambient water-level data, a step test was conducted on 2 June 1999 in pumping PW. This step test was performed to determine an optimal pumping rate for the subsequent constant-rate test by measuring the pumping rate and drawdown and establishing a rate that adequately stressed the aquifer without dewatering the well. A submersible centrifugal pump, powered by a portable 440 amp generator was used. Pumped water was conveyed to a 20,000 gallon portable tank, and the pumping rate was determined with a graduated, five-gallon bucket and a stop watch.

Seven steps were conducted over a period of approximately 200 minutes. Figure 9-5 shows the hydrograph at PW during the step testing and a table of respective pumping rates. Based on the results of the test, a target pumping rate of approximately 20 gallons per minute (gpm) was selected for the constant-rate test. Appendix G contains the raw transducer data from the step test.

9.2.3 Constant-Rate Test

On 7 June 1999, a 72-hour constant-rate pumping test (CRT) was conducted at pumping well PW. Pumping-rate determination, water containerization, and water-level measurement procedures were similar to those used during the step test. In addition, a total of 33 site wells were monitored with portable water-level indicators (WLIs) to calibrate the datalogger and to serve as a backup in the event of datalogger/transducer failure. Appendices H and I contain tabulated data from the datalogger and WLIs, respectively. Prior to the onset of pumping, static water level elevations were determined for each of the wells monitored throughout the aquifer testing (Figure 9-6). The map includes only those wells screened within the upper portion of the unconfined aquifer. Some wells, such as HS and 22 are excluded from the map because they are screened in clay. The water levels measured throughout the testing period are summarized on Table 9-1.

9.3 Evaluation and Results

9.3.1 Hydraulic Analysis

Figure 9-7 shows the hydrograph of observation well OW throughout the testing period. The hydrograph depicts a rapid drop in water level at the start of the constant rate test with minor fluctuations caused by minor adjustments in the pumping rate, followed by steady drawdown over a period of approximately one day. After approximately 1,500 minutes of pumping, the portable generator failed and pumping ceased for 68 minutes until a replacement generator could be brought on-line and the test resumed. Slight fluctuations in the data are evident as the pumping rate was adjusted to original pumping conditions. The maximum fluctuation in pumping rate was 10 percent, and generally, the pumping rate varied by only five percent. Variations occurred only over short periods during the test; therefore, the resultant data are valid for the hydraulic evaluation. The average pumping rate throughout the entire 72-hour period was 18.75 gpm.

Figure 9-8 is the same hydrograph shown on Figure 9-7, but it is extended to show the aquifer recovery following the CRT and includes barometric pressure data collected during the same period. Barometric pressure is monitored during pumping tests to determine the influence, if any, of fluctuating atmospheric pressure on the potentiometric surface in the aquifer. Such an effect is primarily observed in confined aquifers, but prudent practice dictates the monitoring of barometric pressure during all aquifer tests. If an effect is seen, the barometric efficiency of the well is calculated and the drawdown data are adjusted accordingly. For this test, a barometric pressure transducer was connected to the datalogger to record pressure in feet. As shown on Figure 9-8, and as expected for an unconfined aquifer, there was no observed barometric effect on the water table and adjustments were not necessary. The small peak in the recovery data at approximately 11,000 minutes after the start of the CRT resulted when water containerized during the test was released. Figure 9-9 depicts the potentiometric surface on 10 June 1999 near the end of the pumping test.

The drawdown data indicate a delayed-yield response typical of unconfined aquifers. Figure 9-10 shows one example of this response. In Segment 1 of Figure 9-10, the data initially reveal a drawdown curve similar to that expected from a confined aquifer, because water is being released from the elastic storage of the aquifer, not from the pore spaces of the aquifer. Thereafter, in Segment 2, the drawdown rate decreases and the data reveal a more gradual curve as gravity drainage contributes water that was previously held in storage (i.e., within the pore spaces of the sand grains). Eventually, as in Segment 3, the effects of gravity drainage are diminished as the aquifer becomes unsaturated above the cone of depression. Neuman (1974) devised an analytical solution for unconfined aquifers with delayed gravity response. Use of this solution provides estimates of transmissivity, storage coefficient, specific yield, and Beta, a term that relates the aquifer anisotropy and radial distance to the observation well.

Figures 9-11, 9-12, and 9-13 are AQTESOLV™ for Windows™ results of Neuman solutions conducted on drawdown and recovery data from Wells OW, KD, and 28, respectively. Because AQTESOLV™ incorporates the principle of superposition in the analysis to accommodate variable pumping rates (Streltsova, 1988), it is possible to combine both drawdown and recovery (including the short stoppage in pumping when the generator failed) at a well in one solution. Prior to analysis, late drawdown data were corrected for dewatering using Jacob's correction method (Jacob, 1944). The results of the analyses shown on Figures 9-11, 9-12, and 9-13 are summarized below.

Well	T (gpd/ft)	S	Sy	B	b (ft)	k (gpd/ft^2)
OW	3800	5.03E-04	4.69E-02	4.30E-03	23	165
28	4200	1.60E-03	2.29E-02	2.70E-01	18	233
KD	4300	2.40E-04	1.00E-02	1.33E-02	23	187
Mean	*4100*	*7.81E-04*	*2.66E-02*	*9.59E-02*	*21*	*195*

Notes: T = Transmissivity
S = Storativity
Sy = Specific yield
B = Beta
b = Aquifer thickness
k = Hydraulic conductivity

The results indicate a relatively transmissive aquifer, with: (i) an average transmissivity of approximately 4,100 gpd/ft; (ii) a storativity of 8×10^{-4} during the earliest portion of the data, a result that is reasonable for the segment of the test that exhibits a confined aquifer response; and (iii) a specific yield (equivalent to storativity near the end of the test) of approximately 3×10^{-2}, a result that is a reasonable storativity estimate for an unconfined aquifer. At an average saturated thickness of 21 feet, these results yield a hydraulic conductivity estimate of approximately 195 gpd/ft^2 or 26 ft/day. These results are similar to the results obtained previously by Geraghty & Miller.

9.3.2 Chemical Analysis

Throughout the CRT, pH and turbidity were monitored. These results are presented on Table 9-2. In addition, groundwater samples were obtained from the pumping well and analyzed for lead, cadmium, VOCs and general chemical parameters. The results of the chemical analyses of groundwater samples obtained from pumping well PW during the CRT are summarized on Tables 9-3 through 9-5. Trace concentrations of VOCs were detected. The data for lead, cadmium, pH, and turbidity were plotted with time on Figures 9-14 through 9-17. As indicated on Figures 9-14 through 9-17, the concentrations of lead and cadmium in the extracted groundwater were low, relative to the ambient concentrations of lead and cadmium in the groundwater where the extraction well is located. More significantly, the concentrations of lead and cadmium declined during the test. For lead, the concentration was below the level of detection during most of the test. On one occasion, the generator supplying power to the pump stopped. Upon restarting the generator and pump, an increase in turbidity and lead concentration occurred briefly. Thereafter, the flow rate of the pump was altered slightly several times, which also

resulted in minor variations in turbidity and lead concentrations (Figures 9-14 and 9-15).

For cadmium, a steady decline in concentration was noted during the aquifer test. It is anticipated that the concentration of cadmium could have declined to below the level of detection within 12 to 15 days of pumping. However, because the test was performed for only three days, the time required for the concentration of cadmium to decline to the detection level is estimated.

9.3.3 Anticipated Extraction of Lead and Cadmium

When groundwater is extracted for an extended period, the concentrations of any constituents either dissolved in groundwater or entrained in the flow of groundwater tend to asymptotically decline to a minimum as geochemical reactions and dilution occur. In this case, the level to which the concentration of lead is expected to decline is below the level of detection. It is also anticipated that for cadmium, the concentration will be at or below the detection level. Under a long-term pumping scenario, the concentration of inorganics such as lead and cadmium in extracted groundwater may be significantly lower than the respective detection levels.

Assuming that 1 ppb of lead could be extracted continuously at an estimated flow rate of 37 gpm (Section 10) it is estimated that approximately 60 years of pumping would be required to extract a significant amount of the lead remaining in groundwater (Table 9-6). For cadmium, assuming the same extraction rate and an average concentration of 2 ppb in the extracted groundwater, it is estimated that 50 years of pumping would be required to extract a significant mass of the cadmium remaining in groundwater (Table 9-6). These timeframes are theoretical. Achievement of RAOs may occur in shorter periods as a result of the naturally occurring improvement of groundwater quality described above. Therefore, it is expected that extracting small amounts of lead and cadmium through the use of the pump-and-treat technique will not significantly enhance improvement of groundwater quality.

As described in Section 12, the results of modeling confirm that extracting significant amounts of lead and cadmium from the aquifer is infeasible. In fact, extracting lead and cadmium by pumping groundwater is so ineffective that it will not contribute significantly to achievement of RAOs. Therefore, the implementation of a pump-and-treat remedy for this site is impractical.

GROUNDWATER LEVELS PRIOR TO AND AFTER COMPLETION OF THE PUMPING TEST

Phase II Groundwater Evaluation
NL Industries Superfund Site
Pedricktown, New Jersey

PRE-TEST GROUNDWATER ELEVATIONS 6/7/99 BETWEEN 1300 AND 1400 HRS.			
WELL	TOC (ft)	DTW (ft)	GW ELEV (ft)
SD	13.39	7.15	6.24
SS	12.7	6.11	6.59
S4-1*	12	5.2	6.8
T2-3	11.34	6.76	4.58
TC	--	7.25	--
T-4	12.12	7.31	4.81
T-A	--	7.58	--
OS	11.95	7.63	4.32
OD	12.47	8.33	4.14
IT	11.19	5.41	5.78
PD	12.86	6.85	6.01
BR	10.82	5.5	5.32
PS	13.89	7.72	6.17
PW	11.55	6.18	5.37
OW	11.83	6.49	5.34
KS	11.54	6.04	5.5
KD	11.77	6.27	5.5
24	13.04	17.56	-4.52
JD	14.02	7.48	6.54
JS	13.89	7.38	6.51
10R	14.02	17.31	-3.29
ID	17.18	10.55	6.63
IS	17.35	8.19	9.16
HD	18.67	13.65	5.02
HS	18.4	13.8	4.6
28	16.4	10.92	5.48
27	16.57	11.07	5.5
30	16.29	11.13	5.16
29	16.26	10.79	5.47
32	14.28	9.77	4.51
31	14.33	9.21	5.12
RD	15.56	9.58	5.98
RS	15.4	7.42	7.98

PUMPING-TEST GROUNDWATER ELEVATIONS 6/10/99 BETWEEN 1300 AND 1400 HRS.			
WELL	TOC (ft)	DTW (ft)	GW ELEV (ft)
SD	13.39	8.17	5.22
SS	12.7	7.01	5.69
S4-1*	12	6.2	5.8
T2-3	11.34	7.02	4.32
TC	--	7.55	--
T-4	12.12	7.66	4.46
T-A	--	7.96	--
OS	11.95	7.96	3.99
OD	12.47	8.58	3.89
IT	11.19	5.6	5.59
PD	12.86	7.09	5.77
BR	10.82	5.74	5.08
PS	11.89	5.96	5.93
PW	11.55	14.5	-2.95
OW	11.83	9.51	2.32
KS	11.54	8.77	2.77
KD	11.77	9.27	2.5
24	13.04	17.92	-4.88
JD	14.02	7.91	6.11
JS	13.89	7.82	6.07
10R	14.02	17.67	-3.65
ID	17.18	10.83	6.35
IS	17.35	8.43	8.92
HD	18.67	13.89	4.78
HS	18.4	14.03	4.37
28	16.4	11.96	4.44
27	16.57	12.03	4.54
30	16.29	11.36	4.93
29	16.26	11.1	5.16
32	14.28	9.97	4.31
31	14.33	9.4	4.93
RD	15.56	9.77	5.79
RS	15.18	7.57	7.61

DIFFERENCE	DRAWDOWN
(ft)	(ft)
1.02	1.02
0.9	0.9
1	1
0.26	--
--	--
0.35	--
--	--
0.33	--
0.25	--
0.19	--
0.24	--
0.24	--
0.24	--
8.32	8.32
3.02	3.02
2.73	2.73
3	3
0.36	--
0.43	--
0.44	--
0.36	--
0.28	--
0.24	--
0.24	--
0.23	--
1.04	1.04
0.96	0.96
0.23	--
0.31	--
0.2	--
0.19	--
0.19	--
0.37	--

Notes

1) TOC for Wells PW, OW, OS, OD, KS, KD, HS, HD, SS, T-4, RS, RD, PS, 24, 28, 27, 30, 29, 32, and 31 adjusted by adding 1.12 feet to convert from NAVD 1988 to NGVD 1929.

2) Shaded cells denote wells used in construction of shallow potentiometric surface maps and flow model.

3) Water-level differences less than 0.9 feet are attributed to the natural decline of the water table during the 1999 drought and do not represent drawdown.

* TOC is estimated.

TABLE 9-2

SUMMARY OF GROUNDWATER pH and TURBIDITY[1] DURING AQUIFER TEST

Phase II Groundwater Evaluation
NL Industries Superfund Site
Pedricktown, New Jersey

Sample Designation	Date	Time	Turbidity[2]	pH[3]
PT-1-060799	06/07/1999	1500	1.40	3.23
PT-2-060799	06/07/1999	1537	0.60	3.11
PT-3-060799	06/07/1999	1630	NT	3.58
PT-4-060799	06/07/1999	1730	0.85	3.15
PT-5-060899	06/08/1999	130	0.30	3.69
PT-6-060899	06/08/1999	930	0.67	3.41
PT-7-060899	06/08/1999	1720	0.86	3.2
PT-8-060999	06/09/1999	1330	0.94	2.94
PT-9-060999	06/09/1999	1020	0.87	3.32
PT-10-060999	06/09/1999	1750	0.92	3.25
PT-11-061099	06/10/1999	130	0.00	3.11
PT-12-061099	06/10/1999	930	1.38	3.28
PT-13-061099	06/10/1999	1415	1.90	3.15

TABLE 9-3

SUMMARY OF VOLATILE ORGANIC COMPOUNDS DETECTED DURING AQUIFER TEST

Phase II Groundwater Evaluation
NL Industies Superfund Site
Pedricktown, New Jersey

Sample Designation	Date	Time	Chloroform, ug/L	Toluene, ug/L
PT-1-060799	06/07/1999	1500	0.23 J	0.17 J
PT-8-060999	06/09/1999	1330	0.25 J	0.25 J
PT-13-061099	06/10/1999	1415	0.19 J	ND
TRIP BLANK	06/09/1999	NA	ND	ND
TRIP BLANK	06/10/1999	NA	ND	ND
QA/QC Samples				
QA-1	06/10/1999	NA	ND	ND
PT-ERB-060799	06/07/1999	930	ND	ND

Notes:

J - estimated concentration below reporting limit

ND - Not detected above the method detection limit

NA - Not applicable

TABLE 9-4

SUMMARY OF LEAD AND CADMIUM IN GROUNDWATER EXTRACTED DURING AQUIFER TEST

Phase II Groundwater Evaluation
NL Industries Superfund Site
Pedricktown, New Jersey

Sample Designation	Date	Time	Total Lead	Dissolved Lead	Total Cadmium	Dissolved Cadmium
PT-1-060799	06/07/1999	1500	6.1	4.6	43.9	45.2
PT-2-060799	06/07/1999	1537	3.0	1.4B	45.7	46.3
PT-3-060799	06/07/1999	1630	1.7B	ND	47.8	48.3
PT-4-060799	06/07/1999	1730	2.7B	ND	46.2	46.1
PT-5-060899	06/08/1999	0130	6.6	ND	44.8	43.9
PT-6-060899	06/08/1999	930	2.2B	ND	42.9	42.9
PT-7-060899	06/08/1999	1720	1.6B	ND	42.2	41.5
PT-8-060999	06/09/1999	0130	9.3	5.3	41.0	38.7
PT-9-060999	06/09/1999	1020	3.4	ND	39.2	38.9
PT-10-060999	06/09/1999	1750	2.9B	ND	39.0	38.2
PT-11-061099	06/10/1999	0130	ND	ND	38.0	37.9
PT-12-061099	06/10/1999	930	7.0	1.5B	36.8	37.2
PT-13-061099	06/10/1999	1415	1.7B	1.2B	37.3	35.3
QA/QC Samples						
PT-DUPLICATE-061099	06/09/1999	--	ND	ND	36.4	36.2
QA-1	06/10/1999	--	4.5	ND	36.5	35.0
PT-ERB-060799	06/07/1999	930	5.5	0.94B	0.85B	ND

Notes:
(1) Measurements obtained using portable field instruments
(2) Turbidity reported in nephelometric turbidity units (NTUs)
(3) pH reported in standard units (SU)
(4) All concentrations in ug/L (ppb)

TABLE 9-5

SUMMARY OF GENERAL GROUNDWATER CHEMISTRY[1] DURING AQUIFER TEST

Phase II Groundwater Evaluation
NL Industies Superfund Site
Pedricktown, New Jersey

Sample Designation	Date	Time	Bicorbonate Alkalinity	Carbonate Alkalinity	Chloride	Sulfate
PT-1-060799	06/07/1999	1500	ND	ND	53.4	3750
PT-8-060999	06/09/1999	1330	ND	ND	46.4	3200
PT-13-061099	06/10/1999	1415	ND	ND	40	2920
QA/QC Samples						
QA-1[2]	06/10/1999	1420	ND	ND	40.3	2780
PT-ERB-060799[3]	06/07/1999	930	13.2	ND	4.9	1.2

Sample Designation	Date	Time	Total Phosphorous	Total Dissolved Solids	Total Suspended Solids
PT-1-060799	06/07/1999	1500	ND	5260	6.4
PT-8-060999	06/09/1999	1330	ND	4300	ND
PT-13-061099	06/10/1999	1415	ND	3780	ND
QA/QC Samples					
QA-1[2]	06/10/1999	1420	ND	3720	ND
PT-ERB-060799[3]	06/07/1999	930	0.12	153	ND

Notes:
1 - Results reported in milligrams per liter (mg/L)
2 - Blind duplicate sample of PT-13-061099
3 - Equipment rinsate blank sample

TABLE 9-6

ESTIMATED PERFORMANCE OF PUMP AND TREAT TECHNIQUE

Phase II Groundwater Evaluation
NL Industries Superfund Site
Pedricktown, New Jersey

From mass calculations (Table 2-1): Mass of lead in groundwater = 9 lbs
Mass of cadmium in groundwater = 14 lbs

From Capture Zone Evaluation (Section 12): Estimate average total groundwater extraction rate = 37 gpm = 0.05 mgd

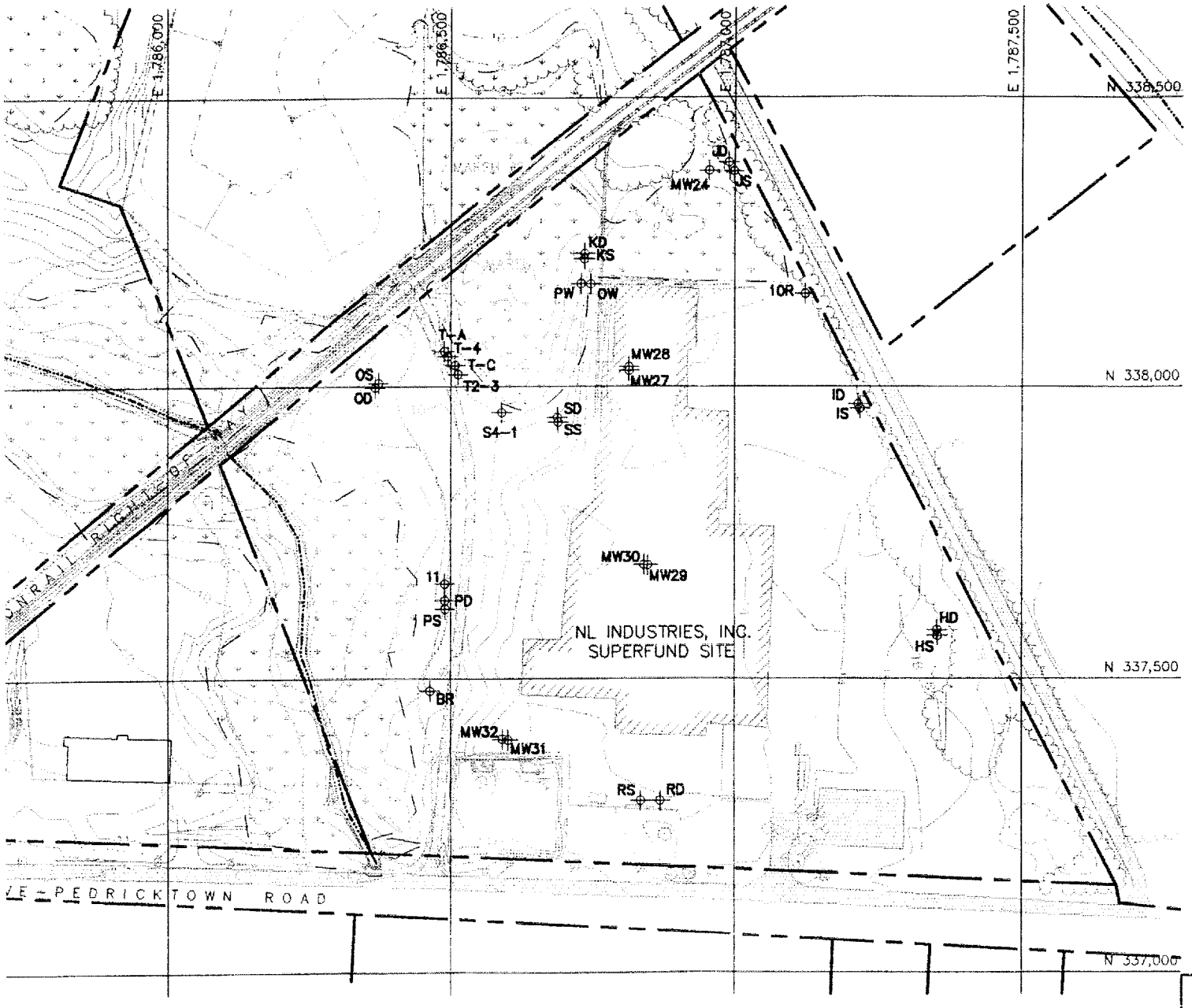
Time required to extract lead (if possible): .001 mg/L*8.34*0.05 mgd = 0.0004 lbs of lead per day extracted

$$\frac{9\,\text{lbs}}{0.0004\,\text{lbs/d}} = 225\,\text{days} = 61\,\text{years (if possible)}$$

Time required to extract cadmium (if possible): .002 mg/L * 8.34 x 0.05 mgd = 0.0008 lbs of cadmium per day extracted

$$\frac{14\,\text{lbs}}{0.0008\,\text{lbs/d}} = 17{,}500\,\text{days} = 48\,\text{years (if possible)}$$

Note: Concentrations of lead and cadmium in extracted groundwater are expected to be non-detectable at steady state. Therefore, assume average concentrations of lead in extracted groundwater to be 1 ppb. For cadmium, assume the concentration will be up to 2 ppb to be conservative. It is possible that the concentrations of lead and cadmium in extracted groundwater will be lower than estimated.



LEGEND

- PROPERTY BOUNDARY
- CONTOUR OF EXISTING GROUND SURFACE (FT, MSL)
- EXISTING FENCE
- EXISTING RAILROAD LINE
- EXISTING TREELINE
- EXISTING STREAM
- EXISTING ROAD
- EXISTING WETLAND (SEE NOTE 4)
- APPROXIMATE LIMITS OF EXPOSED CONCRETE FOUNDATION
- EXISTING BUILDING
- MW27 — GROUNDWATER MONITORING WELL USED DURING AQUIFER TEST

200 100 0 200

SCALE IN FEET

UNDARY IS APPROXIMATE AND IS BASED ON A TOPOGRAPHIC SURVEY Y ALBERT A. FRALINGER, BRIDGETON, NEW JERSEY, MAY 1990.

ACE ELEVATIONS ARE BASED ON AERIAL PHOTOGRAPHY AND GROUND) MARCH 1996 BY OHM REMEDIATION SERVICES CORP.

RE BASED ON NATIONAL GEODETIC VERTICAL DATUM (NGVD) 1929. ONTROL BASED ON NEW JERSEY STATE PLANE COORDINATE SYSTEM

4. WETLAND AREAS ALONG THE WEST STREAM WERE DELINEATED BY PENNONI ASSOCIATES, INC. FROM FIELD SURVEYS CONDUCTED BETWEEN 5 FEB AND 13 FEB 1999; ALL OTHER WETLANDS ARE BASED ON AREAS DELINEATED BY TALBOT & ASSOCIATES, DECEMBER 1990.

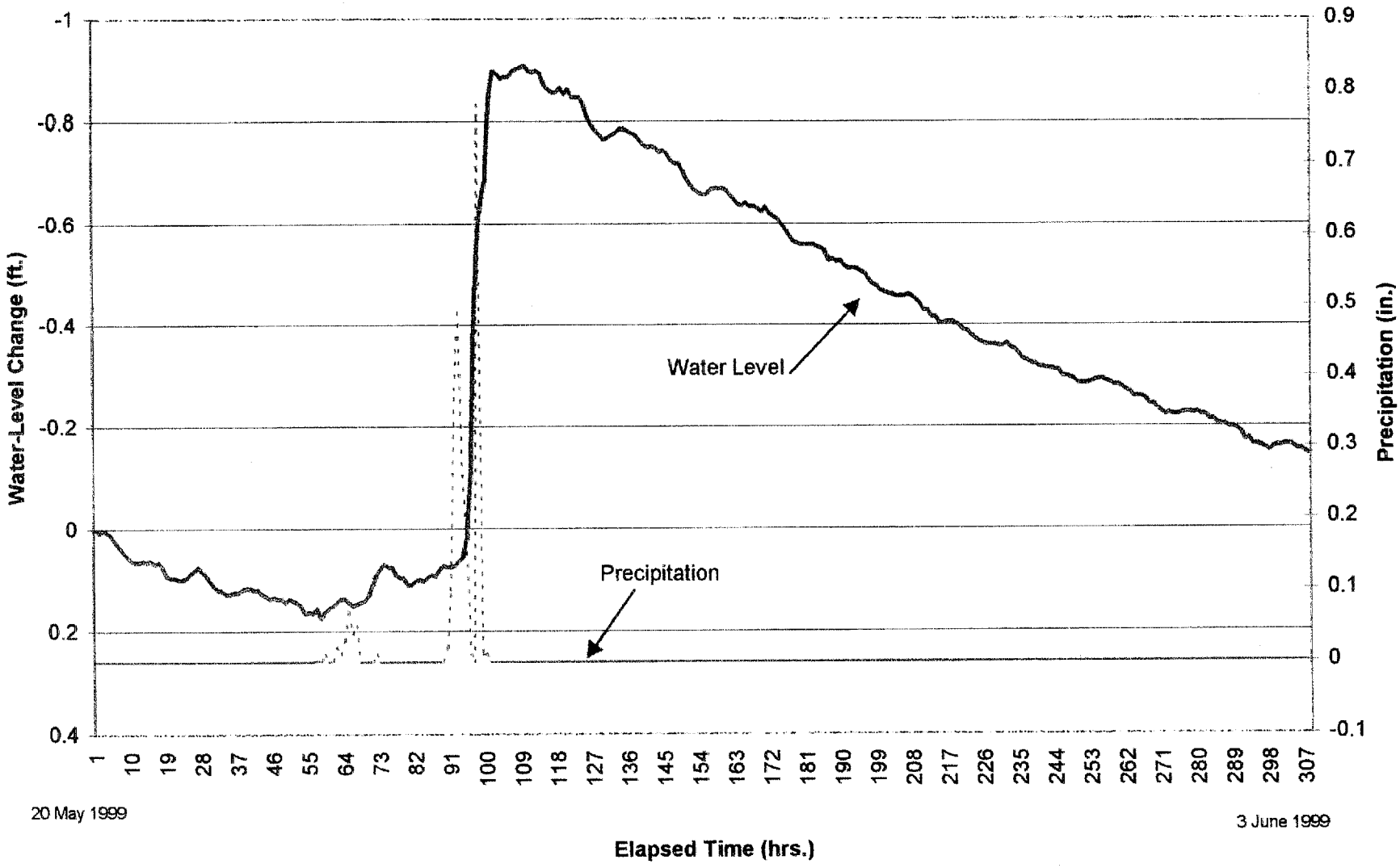
WELL LOCATION PLAN FOR AQUIFER TEST

GeoSyntec Consultants

COLUMBIA, MARYLAND

PROJECT NO. MR0015-15	FIGURE NO. 9-1
DOCUMENT NO. —	FILE NO. 0015F108

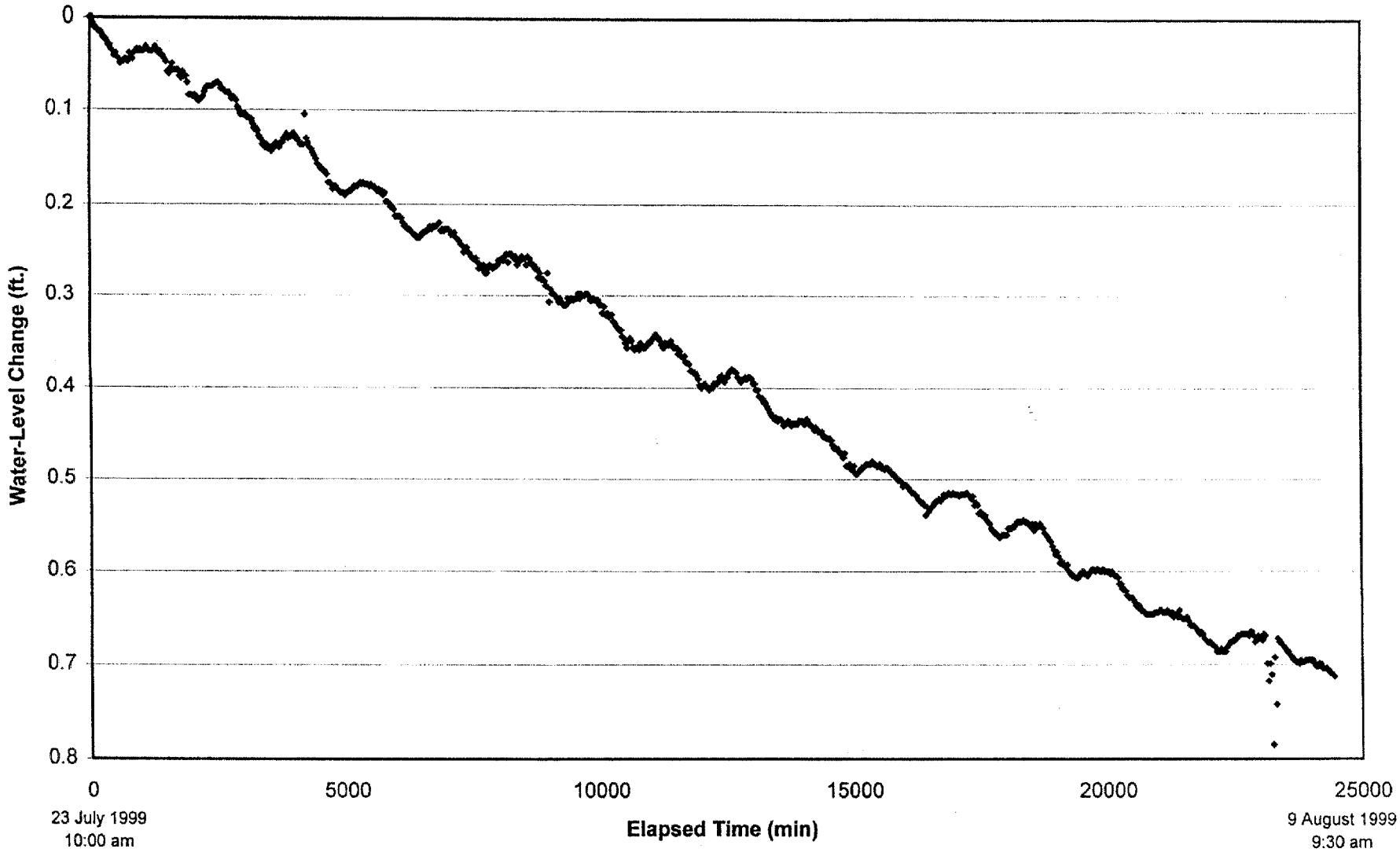
PRE-TEST WATER LEVEL CHANGES AT WELL OW



GeoSyntec Consultants
COLUMBIA, MARYLAND

FIGURE NO.	9-2
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118

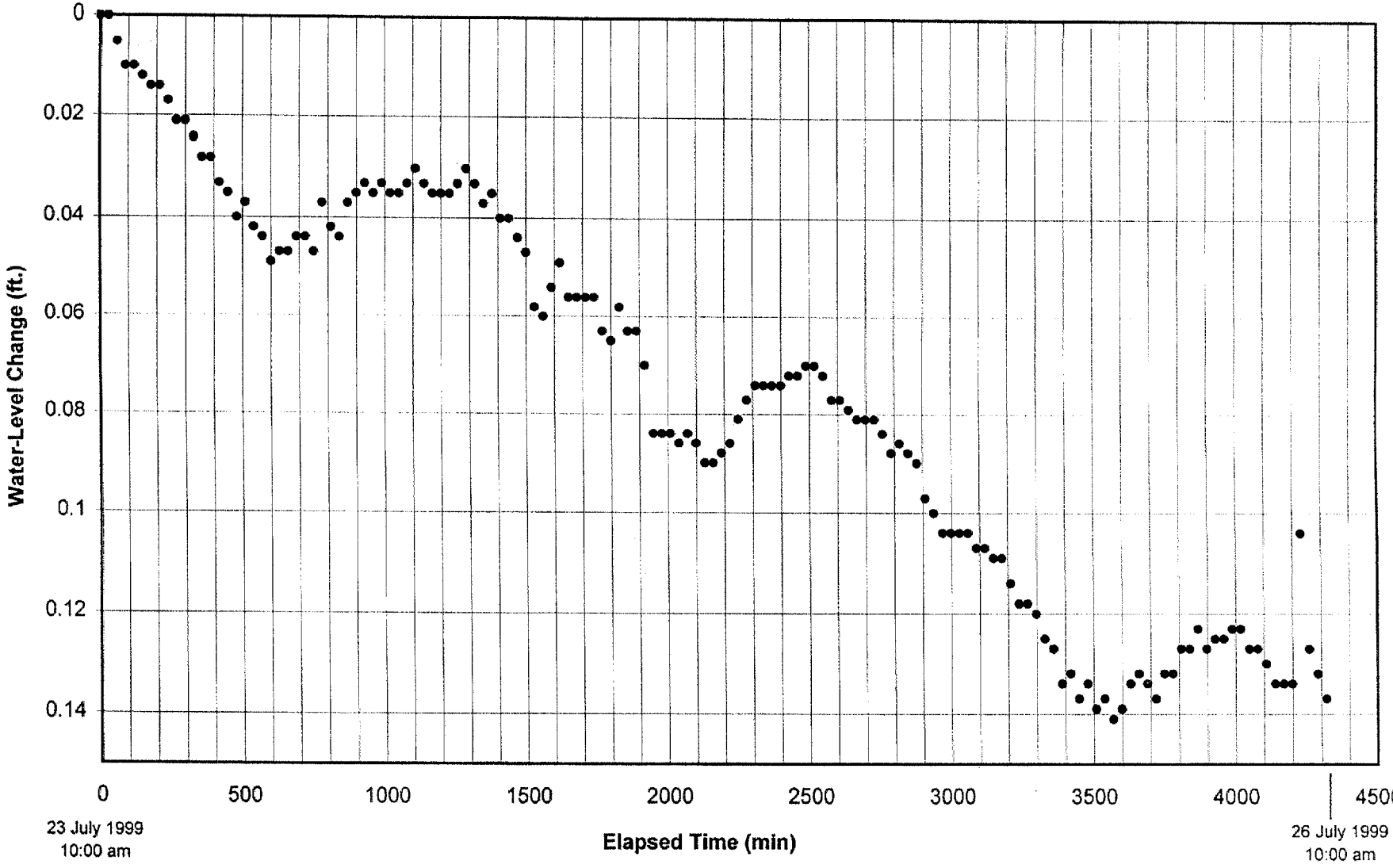
POST-TEST WATER LEVELS AT WELL PW



GeoSyntec Consultants
COLUMBIA, MARYLAND

FIGURE NO.	9-3
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118

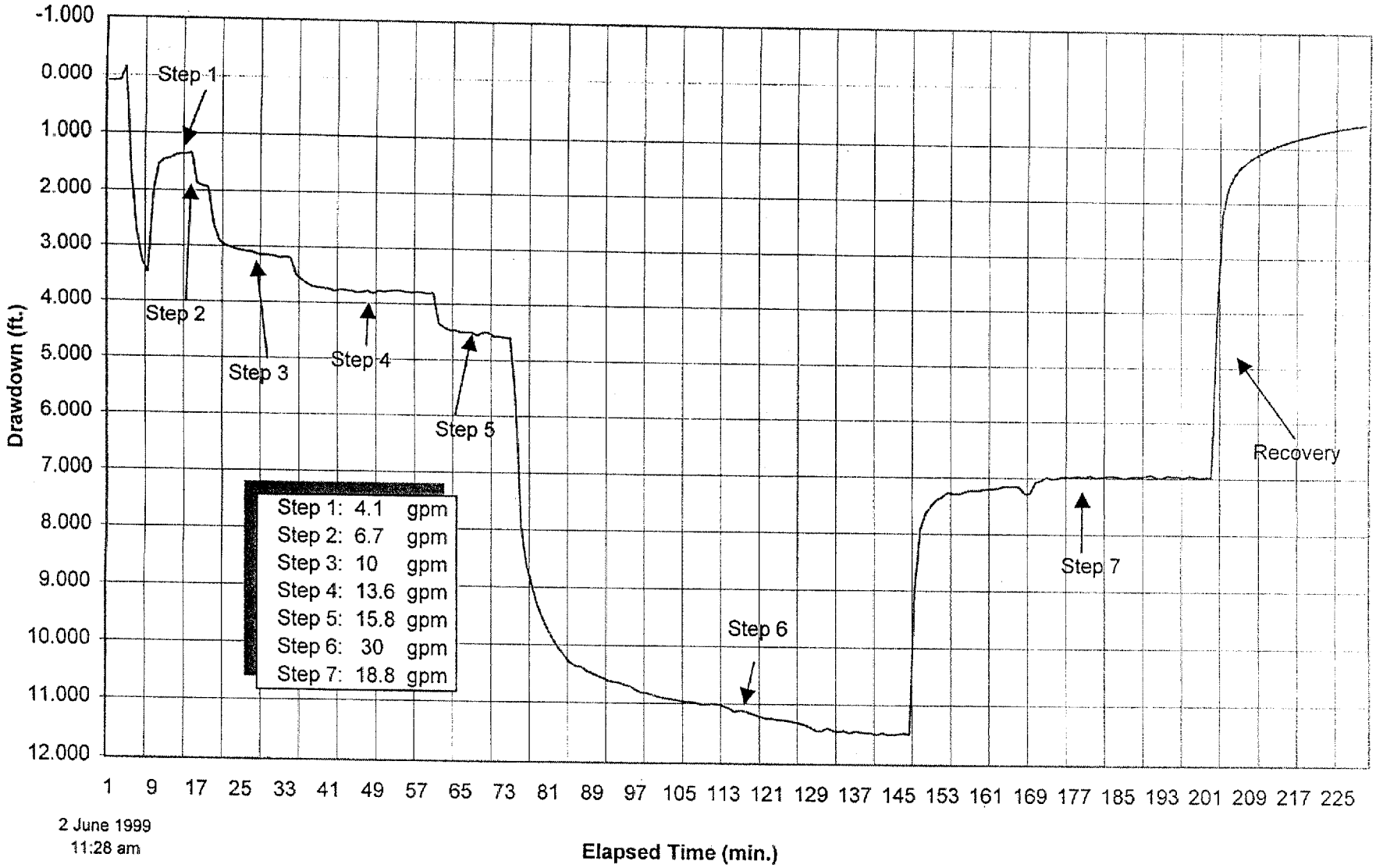
POST-TEST WATER LEVELS AT WELL PW (PARTIAL)



GeoSyntec Consultants
COLUMBIA, MARYLAND

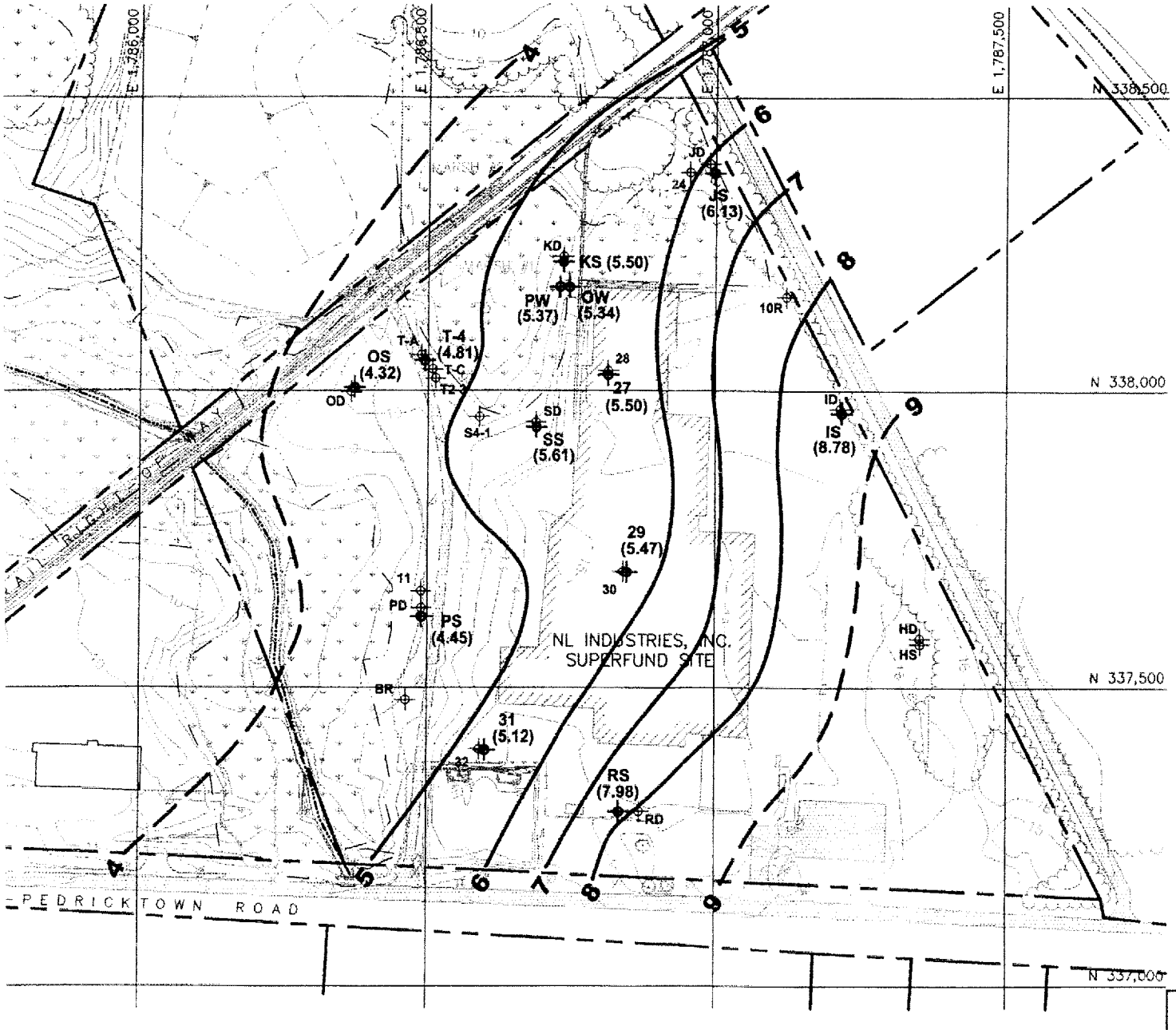
FIGURE NO.	9-4
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118

STEP-TEST HYDROGRAPH AT WELL PW



GeoSyntec Consultants
COLUMBIA, MARYLAND

FIGURE NO.	9-5
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118



LEGEND

- PROPERTY BOUNDARY
- CONTOUR OF EXISTING GROUND ELEVATION (FT. MSL)
- EXISTING FENCE
- EXISTING RAILROAD LINE
- EXISTING TREELINE
- EXISTING STREAM
- EXISTING ROAD
- EXISTING WETLAND (SEE NOTE 4)
- APPROXIMATE LIMITS OF EXPOSED CONCRETE FOUNDATION
- EXISTING BUILDING
- POTENTIOMETRIC SURFACE CONTOUR (DASHED WHERE INFERRED)
- 29 — GROUNDWATER MONITORING WELL USED DURING AQUIFER TEST
- (5.47) — GROUNDWATER ELEVATION

200 100 0 200

SCALE IN FEET

Y IS APPROXIMATE AND IS BASED ON A TOPOGRAPHIC SURVEY RT A. FRALINGER, BRIDGETON, NEW JERSEY, MAY 1990.

EVATIONS ARE BASED ON AERIAL PHOTOGRAPHY AND GROUND H 1996 BY OHM REMEDIATION SERVICES CORP.

SED ON NATIONAL GEODETIC VERTICAL DATUM (NGVD) 1929. L BASED ON NEW JERSEY STATE PLANE COORDINATE SYSTEM

4. WETLAND AREAS ALONG THE WEST STREAM WERE DELINEATED BY PENNONI ASSOCIATES, INC. FROM FIELD SURVEYS CONDUCTED BETWEEN 5 FEB AND 13 FEB 1999; ALL OTHER WETLANDS ARE BASED ON AREAS DELINEATED BY TALBOT & ASSOCIATES, DECEMBER 1990.

POTENTIOMETRIC SURFACE SHALLOW UNCONFINED AQUIFER 6/7/99 (PRE-PUMPING)

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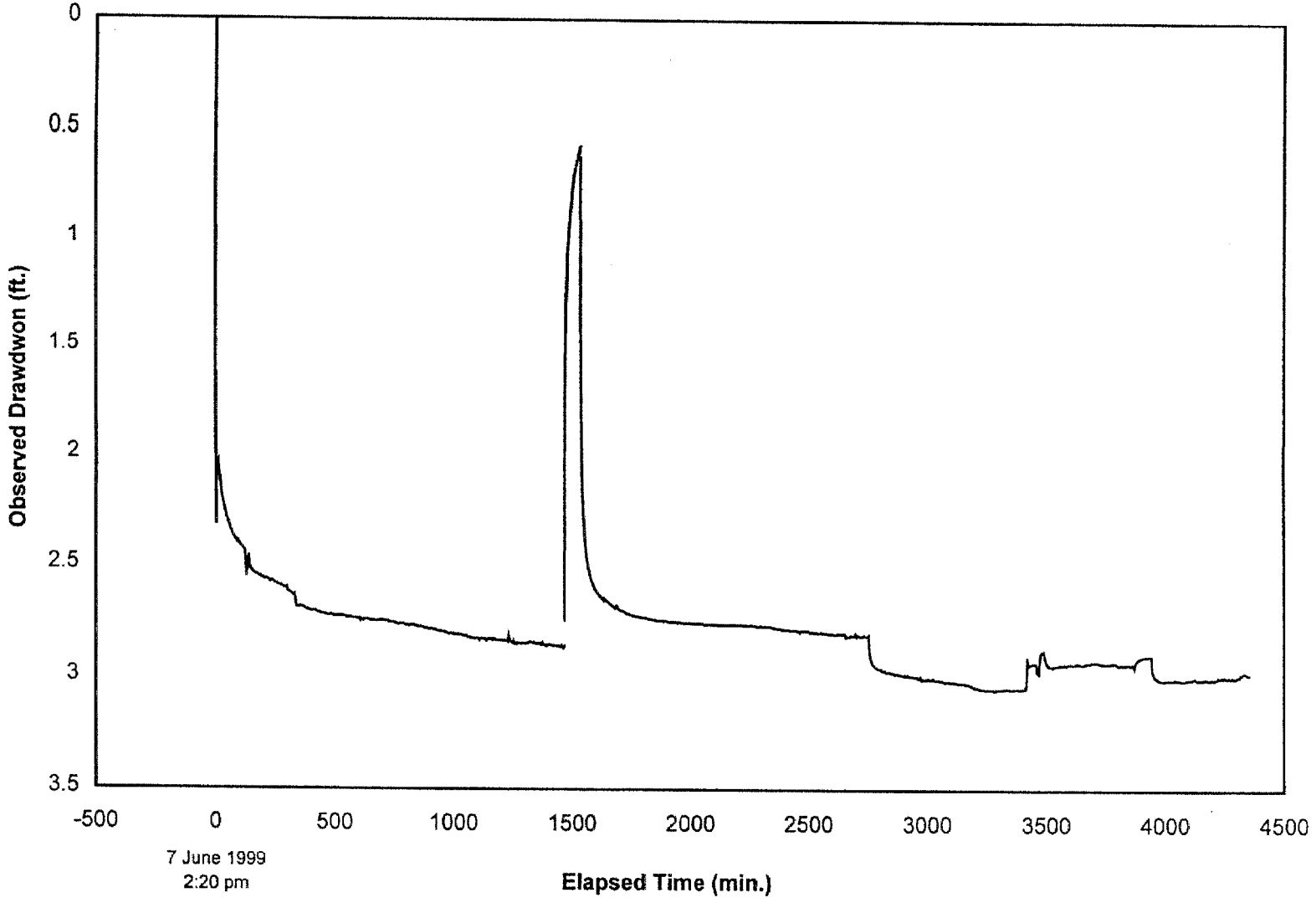
COLUMBIA, MARYLAND

PROJECT NO.	MR0015-15	FIGURE NO.	9-6
DOCUMENT NO.	--	FILE NO	0015F111

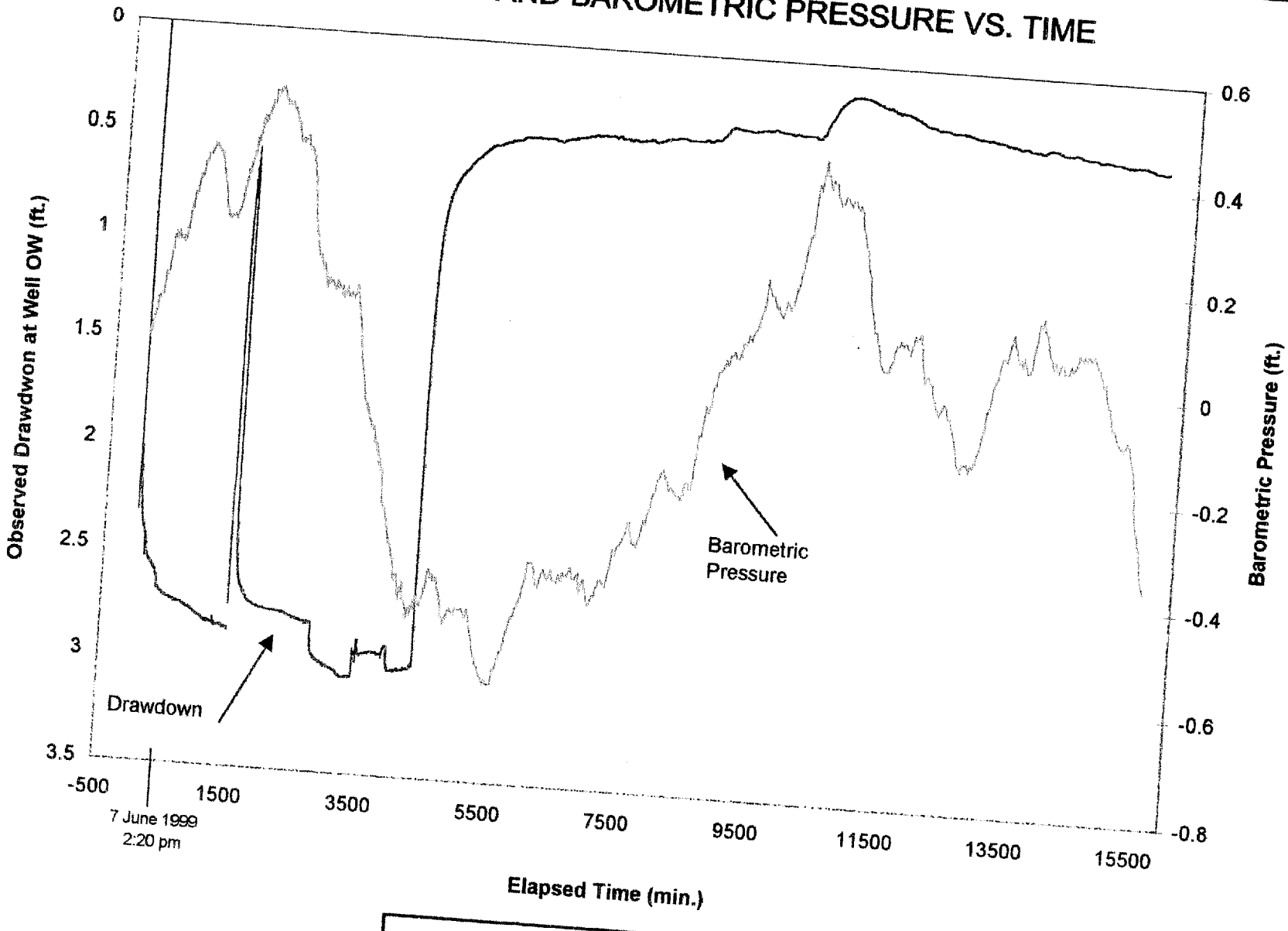
HYDROGRAPH AT OW (RAW DATA)



GeoSyntec Consultants
COLUMBIA, MARYLAND

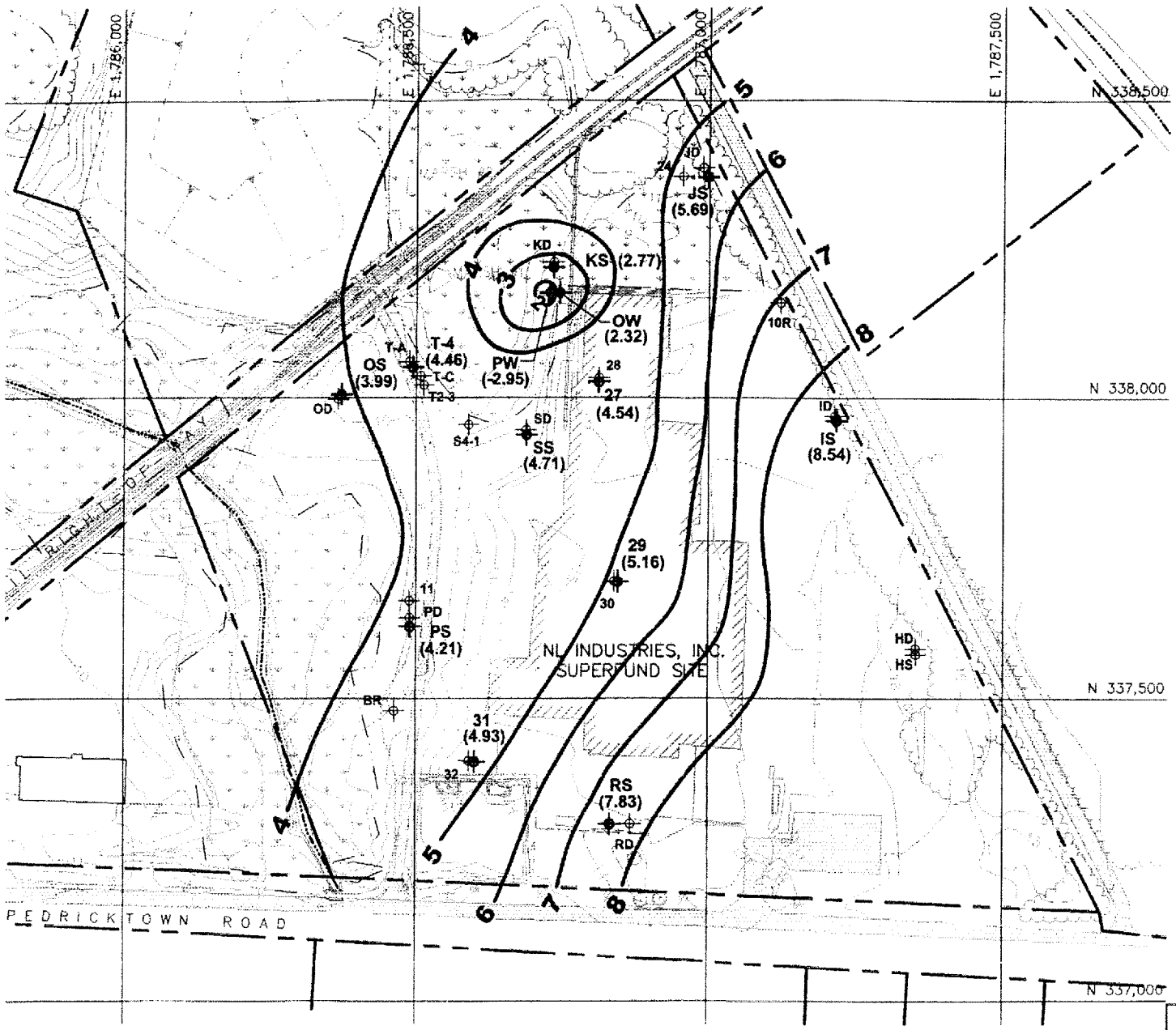
FIGURE NO.	9-7
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118

DRAWDOWN AND BAROMETRIC PRESSURE VS. TIME



GeoSyntec Consultants
COLUMBIA, MARYLAND

FIGURE NO.	9-8
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118



LEGEND

- PROPERTY BOUNDARY
- CONTOUR OF EXISTING GROUND SURFACE (FT, MSL)
- EXISTING FENCE
- EXISTING RAILROAD LINE
- EXISTING TREELINE
- EXISTING STREAM
- EXISTING ROAD
- EXISTING WETLAND (SEE NOTE 4)
- APPROXIMATE LIMITS OF EXPOSED CONCRETE FOUNDATION
- EXISTING BUILDING
- POTENTIOMETRIC SURFACE CONTOUR (DASHED WHERE INFERRED)
- 29 — GROUNDWATER MONITORING WELL USED DURING AQUIFER TEST
- (5.16) — GROUNDWATER ELEVATION

200 100 0 200

SCALE IN FEET

S APPROXIMATE AND IS BASED ON A TOPOGRAPHIC SURVEY
A. FRALINGER, BRIDGETON, NEW JERSEY, MAY 1990.

VATIONS ARE BASED ON AERIAL PHOTOGRAPHY AND GROUND
1996 BY OHM REMEDIATION SERVICES CORP.

) ON NATIONAL GEODETIC VERTICAL DATUM (NGVD) 1929.
BASED ON NEW JERSEY STATE PLANE COORDINATE SYSTEM

4. WETLAND AREAS ALONG THE WEST STREAM WERE DELINEATED BY PENNONI ASSOCIATES, INC. FROM FIELD SURVEYS CONDUCTED BETWEEN 5 FEB AND 13 FEB 1999; ALL OTHER WETLANDS ARE BASED ON AREAS DELINEATED BY TALBOT & ASSOCIATES, DECEMBER 1990.

POTENTIOMETRIC SURFACE SHALLOW UNCONFINED AQUIFER 6/10/99 (PUMPING)

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PROJECT NO. MR0015-15	FIGURE NO. 9-9
DOCUMENT NO. -	FILE NO. 0015F112

DRAWDOWN VS. TIME AT WELL KD

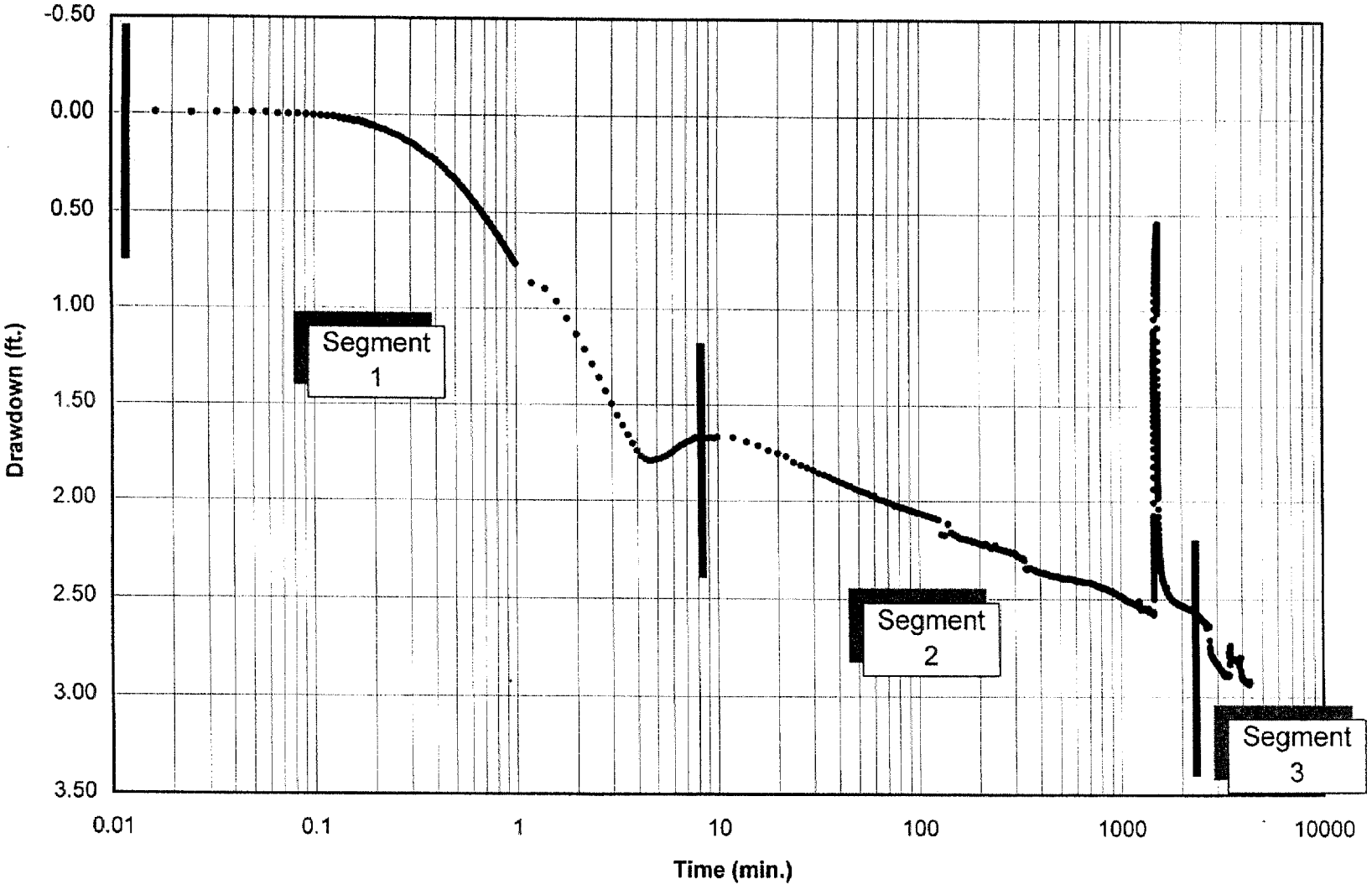

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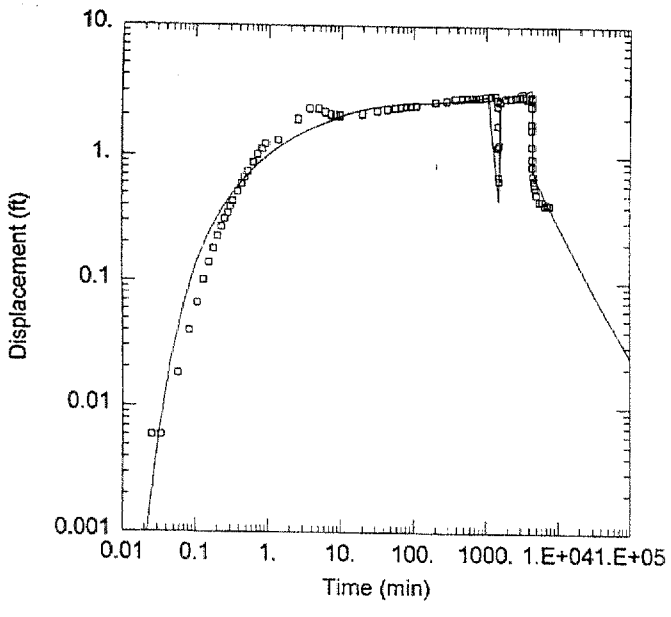
FIGURE NO.	9-10
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118

NEWMAN ANALYSIS AT WELL OW



WELL TEST ANALYSIS

Data Set: J:\WPWORK\DUANE\NL\Pumping Test\OW-4.AQT
Date: 01/03/00 Time: 16:38:21

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 3828.6 gal/day/ft
S = 0.0005025
Sy = 0.04692
ß = 0.004301

AQUIFER DATA

Saturated Thickness: 23. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
OW	0	16.75

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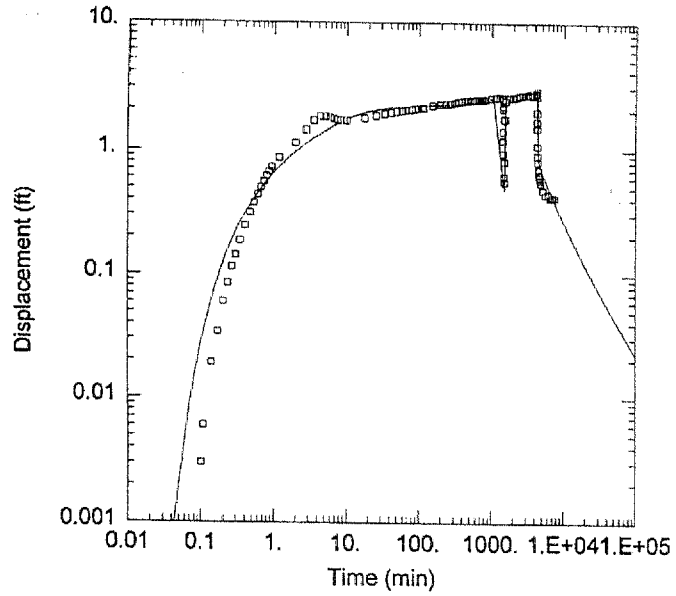
FIGURE NO.	9-11
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118

NEWMAN ANALYSIS AT WELL KD



WELL TEST ANALYSIS

Data Set: J:\WPWORK\DUANE\NL\Pumping Test\KD-4.AQT
Date: 01/04/00 Time: 10:18:00

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 4269.3 gal/day/ft
S = 0.0002404
Sy = 0.01
ß = 0.01325

AQUIFER DATA

Saturated Thickness: 23.5 ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW 1	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
KD	0	36

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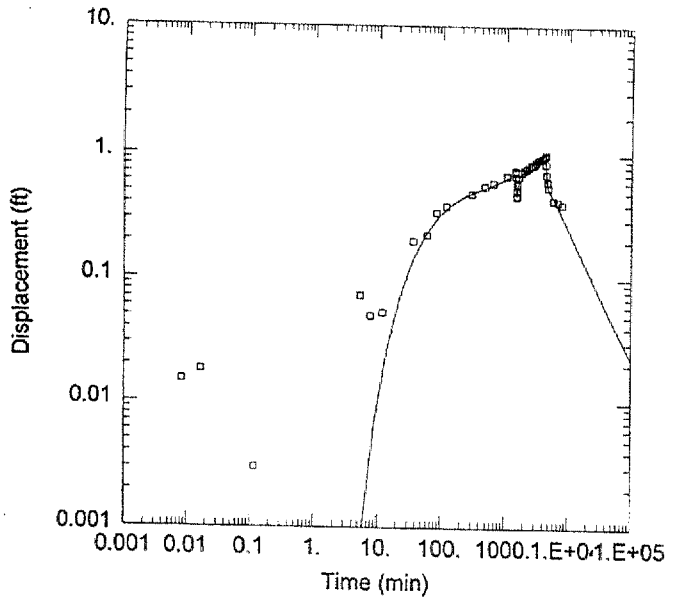
FIGURE NO.	9-12
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118

NEWMAN ANALYSIS AT WELL MW-28



WELL TEST ANALYSIS

Data Set: J:\WPWORK\DUANE\NL\Pumping Test\28-4.AQT
Date: 01/04/00 Time: 10:17:38

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 4190.1 gal/day/ft
S = 0.001601
Sy = 0.0229
ß = 0.2702

AQUIFER DATA

Saturated Thickness: 18. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW 1	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW-28	0	159

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FIGURE NO.	9-13
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118

TOTAL LEAD MEASURED IN EFFLUENT DURING AQUIFER TEST

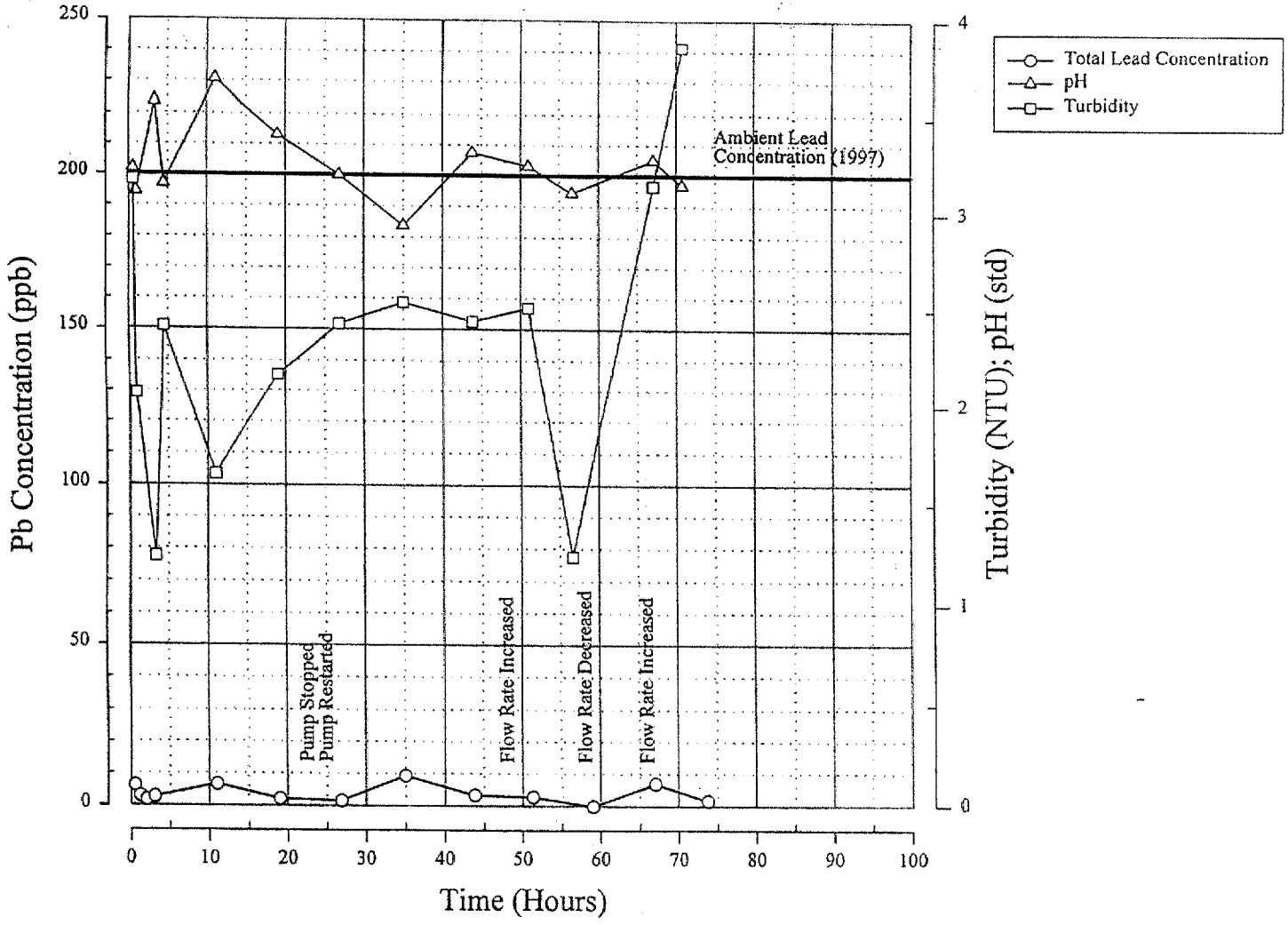

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FIGURE NO.	9-14
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118

DISSOLVED LEAD MEASURED IN EFFLUENT DURING AQUIFER TEST

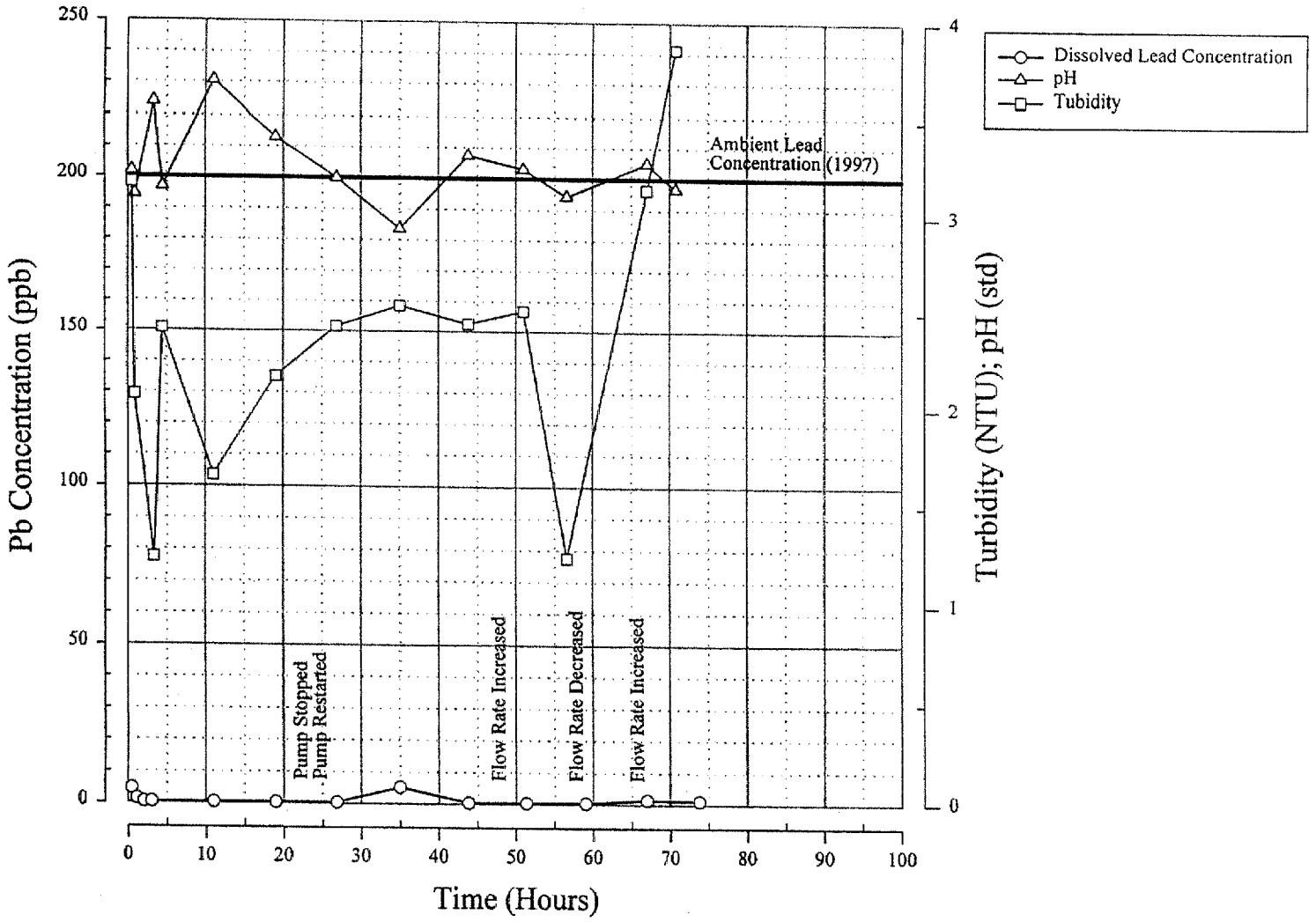

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FIGURE NO.	9-15
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118

TOTAL CADMIUM MEASURED IN EFFLUENT DURING AQUIFER TEST

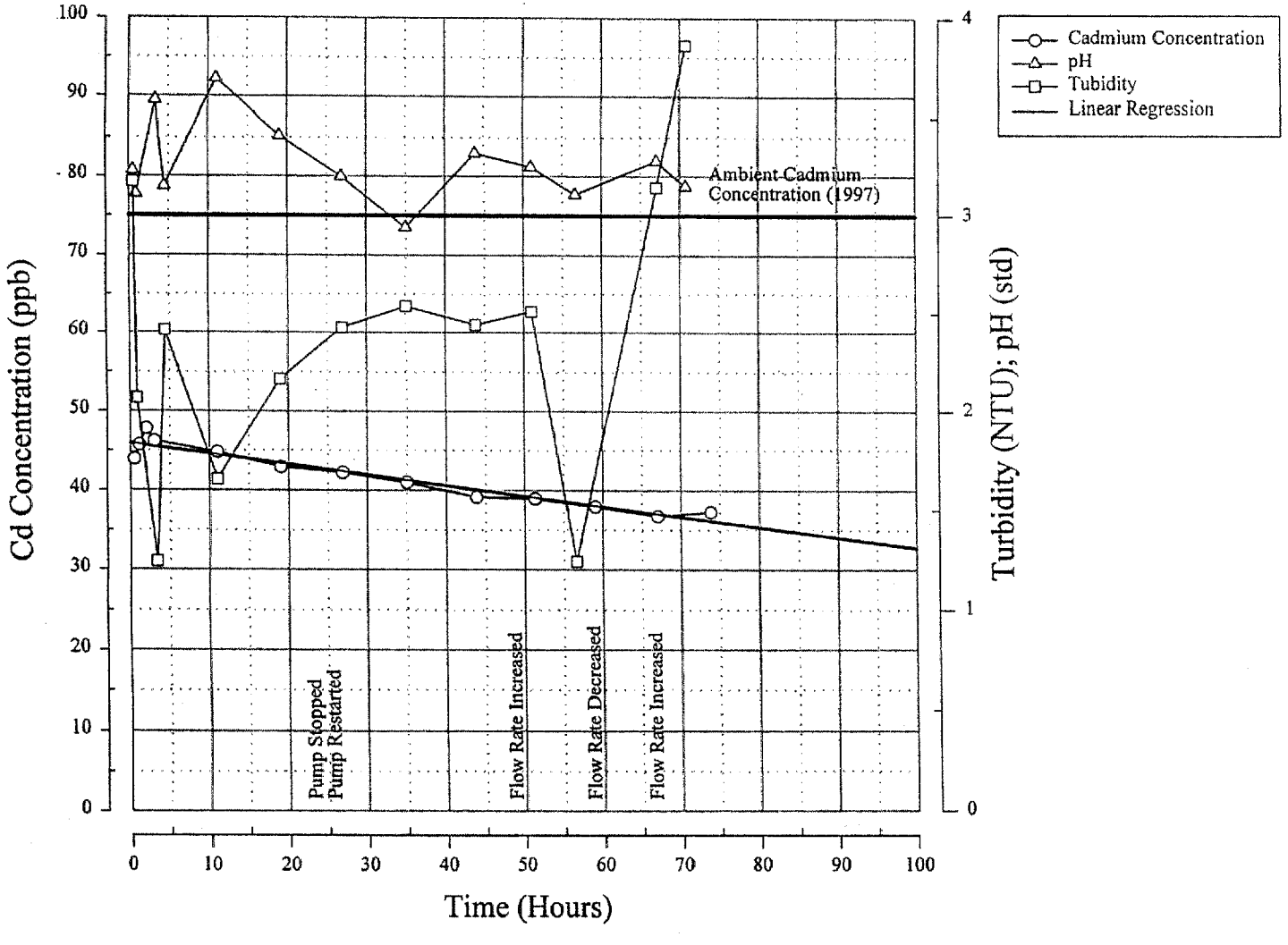

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FIGURE NO.	9-16
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118

DISSOLVED CADMIUM MEASURED IN EFFLUENT DURING AQUIFER TEST

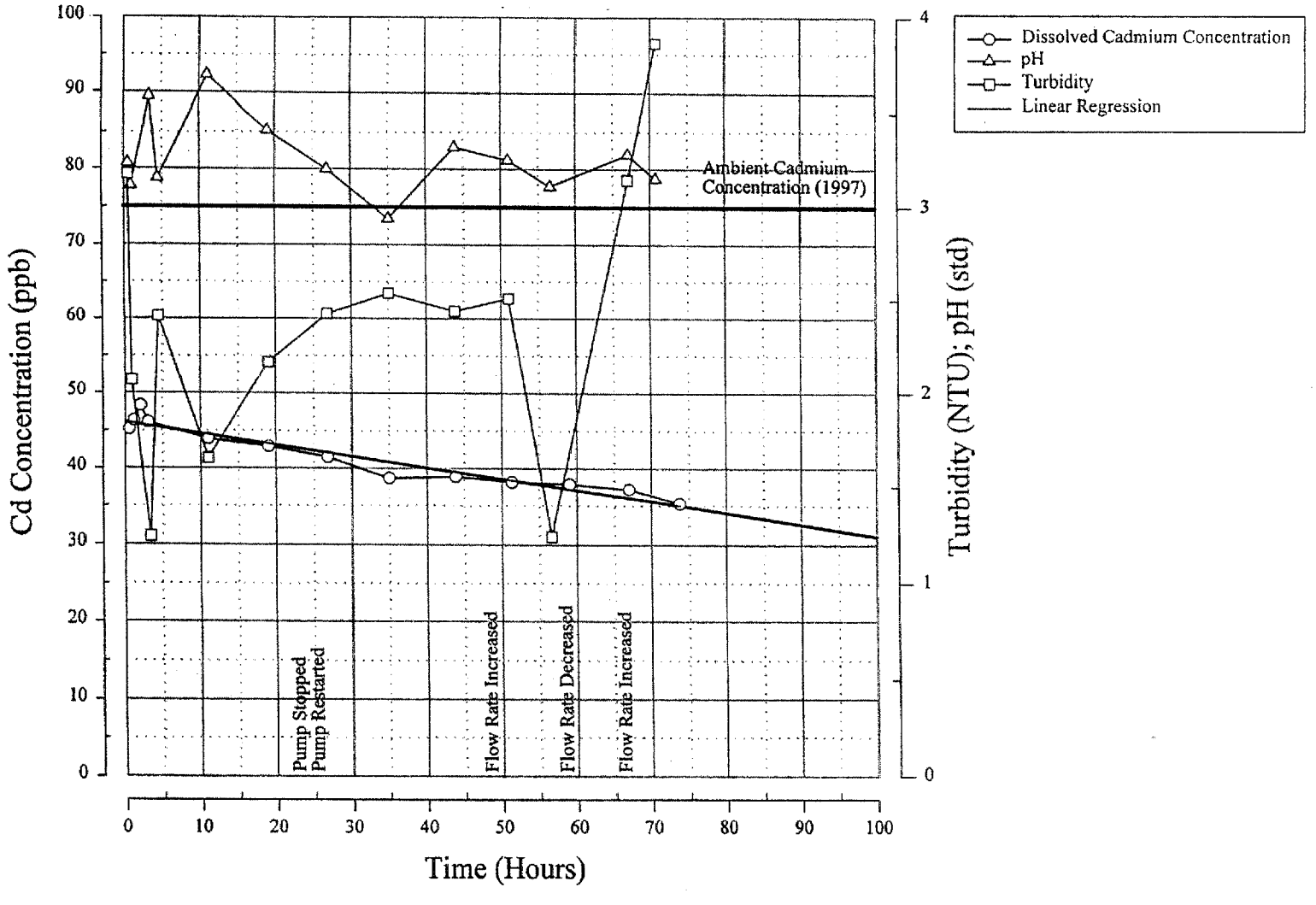

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FIGURE NO.	9-17
PROJECT NO.	ME0015-15
DOCUMENT NO.	
FILE NO.	0015F118